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An assessment of Thorny Skate (*Amblyraja radiata* Donovan, 1808) in NAFO Subdivision 3Ps and Divisions 3LNO

Évaluation de la raie épineuse, (*Amblyraja radiata*, Donovan, 1808) dans la sous-division 3Ps et les divisions 3LNO de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO)

Simpson, M.R., C.M. Miri, and L.G.S. Mello

Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
Science Branch
P.O. Box 5667
St. John's, NL, Canada A1C 5X1

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ABSTRACT

Available information on the fishery, management, and biology of Thorny Skate in NAFO Subdivision 3Ps and Divisions 3LNO were reviewed to determine the status of this stock. Based on a continuous distribution and lack of physical barriers between Subdiv. 3Ps and Div. 3LNO, Thorny Skates in Div. 3LNOPs are considered to constitute a single stock. This stock is managed by Canada in Subdiv. 3Ps, and by the Northwest Atlantic Fisheries Organization in the NAFO Regulatory Area (outside Canada's 200-mile limit) of Div. 3LNO. In Subdiv. 3Ps, with the commencement of a Canadian skate-directed fishery in 1994, NAFO-reported landings averaged 1 308 tons annually over 1994-2009; which decreased to a 808-t average in 2010-11. In 2005-11, reported landings from Div. 3LNO averaged 5 548 tons annually; down from an average of 13 064 t for all countries in 1997-2004. Commercially reported landings data do not include discards at sea, and skate landings are never reported by species; except by Canadian Fisheries Observers. At-sea sampling of Canadian commercial catches for skate lengths by Fisheries Observers was limited in 2010, and non-existent in 2011. An Index of Fishing Mortality for Subdiv. 3Ps remained below 8% since 1996, declined through the late 2000s, and reached its lowest value in 2010-11 (2%). Fishing Mortality in Div. 3LNO increased from the late 1980s to a peak of 29% in 1997; then averaged 17% during 1998-2004. In 2005, this Index reached its lowest value (4%), and subsequently remained below 8%. In Subdiv. 3Ps, Canadian Campelen spring research surveys suggest a gradually increasing trend in Thorny Skate biomass over 1996-2012; averaging 31 400 tons annually. The Subdiv. 3Ps spring survey abundance index was relatively stable in 1996-2012; fluctuating around 23 million skates. After a declining trend in Div. 3LNO over 1985-95 (Engel spring surveys), Campelen spring survey biomass indices followed a gradually increasing trend; averaging 85 500 tons annually. The Div. 3LNO spring abundance index was relatively stable in 1996-2012; fluctuating around 51 million skates. Thorny Skate distribution in Div. 3LNOPs has changed since the 1980s, from a widespread distribution over the Grand Banks in moderate to high concentrations, to a more limited distribution along the southwest edge of the bank in the late 1990s (Div. 3O); Thorny Skate distribution in 2007-12 continued to be concentrated on the southwest boundary of the bank in Div. 3O, in Subdiv. 3Ps, and along the shelf edge of the Grank Banks in Div. 3LN. Length distributions of Thorny Skate sampled in Canadian spring surveys of Subdiv. 3Ps and Div. 3LNO in 1998-2012 indicate that the highest percentage of young-of-the-year skates (5-20 cm TL) for this period was observed in 2009. The primary purpose of this paper is to provide an update on Thorny Skate stock status in Subdiv. 3Ps for use by fisheries managers in formulating conservation measures for this stock.

RÉSUMÉ

Les renseignements disponibles sur la pêche, la gestion et la biologie de la raie épineuse dans la sous-division 3Ps et les divisions 3LNO de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) ont fait l'objet d'un examen pour déterminer l'état de ce stock. D'après une répartition continue et l'absence d'obstacles entre la sous-division 3Ps et les divisions 3LNO, on considère que les raies épineuses présentes dans la division 3LNOPs appartiennent à un seul stock. Ce stock est géré par le Canada dans la sous-division 3Ps et l'OPANO dans la zone réglementée par l'OPANO (à l'extérieur de la limite des 200 milles du Canada) des divisions 3LNO. Dans la sous-division 3Ps, avec le début d'une pêche dirigée de la raie du Canada en 1994, les débarquements signalés par l'OPANO se situaient en moyenne à 1 308 tonnes par année entre 1994 et 2009, pour ensuite diminuer à une moyenne de 808 tonnes en 2010-2011. Entre 2005 et 2011, les débarquements signalés dans les divisions 3LNO se chiffraient en moyenne à 5 548 tonnes annuellement, soit une diminution par rapport à une moyenne de 13 064 tonnes pour tous les pays entre 1997 et 2004. Les données sur les débarquements signalés de la pêche commerciale ne comprennent pas les rejets en mer, et les débarquements de raies ne sont jamais déclarés par espèce, sauf dans les données des observateurs des pêches du Canada. L'échantillonnage en mer des prises commerciales canadiennes portant sur la longueur des raies par les observateurs des pêches a été limité en 2010 et inexistant en 2011. L'indice de la mortalité par la pêche de la sous-division 3Ps est demeuré inférieur à 8 % depuis 1996; il a ensuite décliné jusqu'à la fin des années 2000 pour atteindre sa valeur la plus faible en 2010-2011 (2 %). La mortalité par la pêche dans les divisions 3LNO a augmenté à partir de la fin des années 1980 pour atteindre un sommet de 29 % en 1997 et se stabiliser à une moyenne de 17 % entre 1998 et 2004. En 2005, cet indice a atteint sa valeur la plus faible (4 %) et est ensuite demeuré inférieur à 8 %. Dans la sous-division 3Ps, les relevés de recherche canadiens effectués au printemps à l'aide d'un chalut Campelen suggèrent une tendance graduelle à la hausse dans la biomasse de la raie épineuse entre 1996 et 2012; la moyenne étant de 31 400 tonnes annuellement. L'indice d'abondance des relevés du printemps dans la sous-division 3Ps a été relativement stable entre 1996 et 2012, fluctuant autour de 23 millions de raies. Après une tendance à la baisse dans les divisions 3LNO entre 1985 et 1995 (relevés de printemps avec le chalut Engel), les indices de la biomasse découlant des relevés de printemps avec le chalut Campelen ont suivi une tendance graduelle à la hausse, avec une moyenne de 85 500 tonnes par année. L'indice d'abondance des relevés du printemps dans les divisions 3LNO a été relativement stable entre 1996 et 2012, fluctuant autour de 51 millions de raies. La répartition de la raie épineuse dans la division 3LNOPs a changé depuis les années 1980. Au début, elle était très répandue en concentrations modérées à élevées dans les Grands Bancs, pour ensuite devenir plus restreinte et s'étendre le long de la limite sud-ouest des bancs vers la fin des années 1990 (division 3O). La répartition de la raie épineuse entre 2007 et 2012 continue à se concentrer à la limite sud-ouest des bancs de la division 3O, dans la sous-division 3Ps et le long du bord du plateau des Grands Bancs dans la division 3LN. Selon les répartitions des longueurs de raies épineuses prélevées dans les relevés de printemps canadiens effectués dans la sous-division 3Ps et les divisions 3LNO entre 1998 et 2012, le pourcentage le plus élevé de jeunes raies de l'année (longueur totale de 5 à 20 cm) pour cette période a été observé en 2009. Ce document vise surtout à fournir une mise à jour de l'état du stock de raie épineuse dans la sous-division 3Ps aux gestionnaires des pêches afin de leur permettre de formuler des mesures de conservation pour ce stock.

INTRODUCTION

Thorny Skate (*Amblyraja radiata* Donovan, 1808) is a widely distributed species in temperate and Arctic waters of the North Atlantic. In the western Atlantic, Thorny Skates are distributed from Greenland to South Carolina, and in Newfoundland and Labrador waters (NAFO Div. 2GHJ3KLNOPs), Thorny Skates are found across the continental shelf. Based on the continuous distribution and lack of physical barriers between the south coast of Newfoundland (NAFO Subdivision 3Ps) and the Grand Bank (NAFO Div. 3LNO), Thorny Skate in Div. 3LNOPs is considered to constitute a single stock (Kulka et al. 2004).

Thorny Skates in Div. 3LNOPs have been subjected to commercial fisheries (directed and bycatch) since the beginning of offshore fishing in the late 1940s (Kulka and Mowbray 1999). Commercial catches of skates consist of several skate species; however, Thorny Skate dominates the catch composition. In Canadian commercial catches, about 95% of the skate catch are Thorny Skates (Kulka and Mowbray 1999; Kulka and Miri 2007); similar to the proportion of Thorny Skate in EU-Spain research survey catches in NAFO Div. 3NO (González-Costas et al. 2012). Therefore, the skate fishery in Div. 3LNOPs can be considered a directed fishery for Thorny Skate.

Thorny Skate are relatively vulnerable to overfishing or environmental perturbations. Life history traits such as slow growth, late sexual maturation, low fecundity, and long reproductive cycles result in low inherent rates of population increase for this species, and lead to low resilience to fishing mortality (Stevens et al. 2000; Dulvy and Reynolds 2002; Frisk 2004; Musick 2004; Sosebee et al. 2008; Patrick et al. 2009).

In assessing the Div. 3LNOPs Thorny Skate stock, the primary abundance and distribution indices used are based on the Department of Fisheries and Oceans Canada (DFO) bottom trawl research surveys conducted annually in spring and fall (commencing in 1971 and 1977, respectively). However, the fall survey does not include Subdiv. 3Ps, which contains a considerable proportion of this Thorny Skate stock.

The primary purpose of this paper is to provide an update of Thorny Skate stock status in Subdiv. 3Ps: especially estimations of stock abundance and distribution, as well as other information on commercial landings and fishing mortality for use by fisheries managers in formulating conservation measures for this stock.

FISHERY AND MANAGEMENT

TAC REGULATION

Thorny Skate came under quota regulation in 1995, after a directed skate fishery was established in 1994 by Canada in its Exclusive Economic Zone (EEZ). A Total Allowable Catch (TAC) of 5 000 tons for Div. 3LNO and 1 000 t for Subdivision 3Ps were adopted in 1995; with gear and bycatch policies. In 1996, the TAC was raised to 6 000 t for Div. 3LNO and 2 000 t for Subdiv. 3Ps. In 1997, the TAC was reduced to 1 950 t for Div. 3LNO and 1 050 t for Subdiv. 3Ps. Outside Canada's 200-mile limit, catch was unregulated until September 2004, when the Fisheries Commission of the Northwest Atlantic Fisheries Organization (NAFO) set a TAC of 13 500 tons for 2005-2009 in Div. 3LNO. This quota was lowered by NAFO to 12 000 t for 2010-2011; then to 8 500 t for 2012. The TAC for Subdiv. 3Ps was maintained at 1 050 t.

CATCH TRENDS

In NAFO Subdivision 3Ps, NAFO-reported landings (STATLANT-21A) for all countries combined averaged 505 t during 1970-1979, and increased to 975 t in 1980-1989 (Table 1; Fig. 2,5). During the early 1990s, reported landings of skates in NAFO Subdiv. 3Ps declined to 33 t by 1993. In Subdivision 3Ps, total reported landings averaged 1 308 t from 1994-2009. Landings during 2010 and 2011 averaged 808 t. It should be noted that the TAC was often exceeded over the past thirteen years.

NAFO data also indicated that Canadian fleets reported the majority of Thorny Skate landings in Subdiv. 3Ps from 1994-2008, while St. Pierre and Miquelon (EU-France) annually reported small skate landings; although none were reported by non-Canadian countries in 2009-2011 (Table 1; Fig. 2,5). Prior to commencement of a new Canadian skate-directed fishery in 1994, skates were routinely discarded at sea. Therefore, reported Canadian landings of Thorny Skate in Subdiv. 3Ps rarely exceeded a hundred tons; with the exception of 1977-1981 when Canadian landings averaged 526 t. Reported Canadian landings averaged 1 247 t in 1994-2007, and 567 t in 2008-2011.

In other portions of the stock area (NAFO Div. 3LNO), Kulka and Mowbray (1998) reported that significant bycatch of skates have been taken since commencement of offshore fishing in the late 1940s; initially by non-Canadian fleets and later by Canadian vessels. Prior to the mid 1980s, non-Canadian fleets comprised the largest component of offshore fisheries on the Grand Bank, and took several thousand tons of skate as bycatch each year. The bycatch derived primarily from the Greenland Halibut fishery (*Reinhardtius hippoglossoides*) and from the Canadian mixed fishery for Thorny Skate, White Hake (*Urophycis tenuis*), and Monkfish (*Lophius americanus*; Kulka and Mowbray 1999). Kulka and Mowbray (1998) estimated that approximately 5 000 t on average were discarded annually by Canadian fleets during the 1980s and early 1990s; although only a few hundred tons were recorded in Canada's annual landings statistics during that period. Commercial landings of skates are also never reported by species; except in catch data recorded by Canadian Fisheries Observers at sea.

For Div. 3LNO, NAFO-reported estimates (STATLANT-21A) indicated that landings increased in the mid-to-late 1980s with the commencement of a directed fishery for Thorny Skate (Table 2; Fig. 4,5). In 1985, Spain began targeting skate in a non-regulated fishery in the NRA (Junquera and Paz 1998; del Río and Junquera 2001). In 1985-1991, reported landings averaged 17 000 tons, and peaked at approximately 28 400 t in 1991. This fishery was mainly prosecuted by Spain, Portugal, USSR, and the Republic of Korea. Non-Canadian landings significantly declined to 5 059 t in 1992. In 2000, Russia joined the directed fishery for Thorny Skate. After a peak of 18 277 t in 2000, total catches of skate by all countries in Div. 3LNO declined. In 2005-2011, an average of 5 548 t of Thorny Skate was reported from Div. 3LNO. Furthermore, it should be noted that an annual average of 13 279 t of skate was also landed in 1994-2006 (18 774-ton peak in 2004) by non-Canadian countries, but with no fishing location reported (Table 2). Such NAFO records decreased to a 976-ton average in 2007-2009, and were not available in 2010-2011.

COMMERCIAL SIZE

Sampling of Canadian commercial catches by at-sea Canadian Fisheries Observers indicated that skates caught in Subdiv. 3Ps by the directed bottom trawl fishery in 1999-2007 were 34-97 cm in Total Length (TL), with a mode of 60-67 cm (Fig. 6a; right column). One exception was in 1999, when smaller skates of 18-26 cm TL were also trawled in that fishery, and a dominant mode was seen at 80 cm. Skates trawled in the Subdiv. 3Ps redfish fishery in 2005-2010 were 36-96 cm in length, with a mode of 75-79 cm; although smaller skates of 21+ cm were also caught in 2005, with a mode of 67-68 cm (Fig. 6a; left column). The Canadian skate-

directed gillnet fishery in 2000-2002 caught fish of 49-107 cm (TL), with a mode of 76-80 cm (Fig. 6b; left column). In 2008, Canadian longliners directing for skates in Subdiv. 3Ps caught fish of 52-90 cm TL, with a similar mode of 77-79 cm (Fig. 6b; right column).

In 1999-2008, Canadian gillnetters directing for Monkfish in NAFO Div. 3O caught skates of a size range similar to that observed in Subdiv. 3Ps gillnets: 51-110 cm Total Length (TL), with a mode of 72-77 cm (Fig. 6c; Kulka et al. 2006). The skate-directed Div. 3O longline fishery in 2000 caught 56-101 cm fish, with a dominant mode at 80 cm. Thorny Skates caught in various Canadian fisheries in Div. 3LNOPs were not sampled in 2011.

In 2007-2011, commercial length distributions from EU-Portugal, EU-Spain, and Russia in skate-directed trawl fisheries (280 mm mesh) of Div. 3LNO in the NRA indicated that the range of sizes caught did not vary between EU-Spain and Russia, and were similar to those reported in previous years (Fig. 6d; Kulka et al. 2006). One exception was the distribution of skates caught by EU-Portugal in Div. 3NO: a 25-66 cm range with a mode of 38 cm (2007, 2010) and 42 cm TL (2009) was significantly smaller than those of EU-Spain and Russia (27-95 cm; with a mode of 67 cm). Although these countries used 280 mm mesh in their commercial trawls, this comparison shows that EU-Portugal consistently caught an abbreviated range of smaller skates. Another noteworthy result was reported by EU-Spain in 2008; in which its trawlers also caught a significant mode of 46-49 cm skates (Fig. 6d).

In other directed trawl fisheries (130-135 mm mesh) of Div. 3LNO (NRA) during 2007-2011, length distributions of skate bycatch also did not vary between EU-Spain and Russia (Fig. 6d). However, EU-Portugal caught an abbreviated range of smaller skates in 2007, 2009, and 2010: a 24–72 cm range with a mode of 38 cm (2007), 46 cm (2009), two modes at 54 and 60 cm (2010), and two modes at 60 and 76 cm TL with a maximum length of 84 cm (2011); while EU-Spain caught 26-86 cm skates with a 67-cm mode (2009). In 2008, the size range of skate bycatch reported by EU-Portugal was similar to that of Russian trawlers (28-104 cm with a mode of 58 cm); although Russia also reported a small catch of 12-18 cm young-of-the-year skates. Russia sampled only 59 specimens during the NAFO Div. 3L Greenland halibut fishery in 2009. Thorny Skates varied between 46–76 cm in length; with a mode at 61 cm. Although skate bycatch was not sampled by Russia in 2010, a small sample of 34 skates in 2011 indicated a 43-103 cm range with two modes at 49 and 61 cm.

RESEARCH SURVEY DATA

CANADIAN SPRING SURVEYS

Stratified-random surveys have been conducted by Canadian research vessels in the spring (April-June) of each year from 1971 to 2012. The survey was initiated in Subdivision 3Ps in 1972. A summary of the stratified-random survey design adopted by the DFO-NL Region can be found in Doubleday (1981). While survey design has remained constant, additional strata have been included in recent years, along with modifications to some of the original strata (Bishop 1994). A significant change in the surveys is the addition of shallower and deeper strata after 1993. Additional causes of variation in spring survey coverage are discussed in detail by Brodie and Stansbury (2007), and Healey and Brodie (2009). The spring survey can be split into three time periods, based on the trawl used in each period: 1971-1982 (Yankee), 1983-1995 (Engel), and 1996-2012 (Campelen; McCallum and Walsh 1996). Conversion factors exist for the Engel to Campelen gear change (Simpson and Kulka 2005); however, data from the Yankee gear series have not been converted.

Canadian spring surveys of Subdivision 3Ps showed that mean catch rates for Thorny Skate in 1996-2012 have been relatively stable at low levels (Fig. 7a). The Subdiv. 3Ps spring abundance index fluctuated around 23 million fish in 1996-2012, and averaged 29 million fish in

the Engel years; except for peaks of 55 million fish in 1985 and 50 million fish in 1991 (Campelen-equivalents; Table 3a; Fig. 8a). Spring relative biomass estimates in the Campelen survey years suggest a gradually increasing trend over that time period; with 21 851 tons observed in 1996, and 44 310 t in 2011 (Table 3b; Fig. 8a). The spring biomass estimate for 2012 was 33 699 t.

In Div. 3LNOPs (combined), spring mean catch rates in 1996-2012 have been stable at low levels, but were considerably higher prior to the mid1990s (Fig. 7b). The spring abundance index fluctuated around 73 million fish for Div. 3LNOPs in 1996-2012, and was considerably higher at 114-214 million fish in 1985-92 (Fig. 8b). Similarly, in 1996-2012, relative biomass estimates of 63 000-165 000 t in Div. 3LNOPs were observed; although 156 000-336 000 t previously occurred in 1985-1991.

Considering Div. 3LNO separately in 1996-2012, spring abundance estimates for Thorny Skate in Div. 3L averaged 9 million fish annually; down from an average of 36 million in the Engel years (Campelen-equivalents; Table 3a). The biomass index in Div. 3L also decreased from an annual average of 42 000 tons in 1984-95 to a 12 000-ton average during the Campelen years (Campelen-equivalents; Table 3b). In addition, Div. 3N survey indices declined significantly from Engel to Campelen years: an average annual abundance of 33 million fish decreased to a 15 million-fish average; while an average biomass of 45 000 tons dropped to a 27 000-t average. Spring survey indices in Div. 3O reflected much smaller declines between both time series: annual abundance averaged 31 million fish in 1984-95, as compared to a 27 million-fish average during Campelen years; while biomass averaged 59 000 tons in Engel years, as compared to a 46 000-ton average in 1996-2012.

CANADIAN AUTUMN SURVEYS

Stratified-random autumn surveys have been conducted by Canada in NAFO Div. 3L from 1981 to 2011. In 1990-2011, autumn surveys also extended onto the southern Grand Bank in Div. 3NO. Canadian surveys from 1983-1994 were conducted with an Engel trawl, and from 1995-2011 with a Campelen trawl. It must be noted that Canada does not survey Subdiv. 3Ps in autumn, and did not survey Div. 3NO before 1990. Therefore, autumn survey data are not directly comparable to spring indices (which extend over the entire stock area and time period; except for certain Divisions and years). Furthermore, autumn surveys reach deeper maximum depths (~1 400 m in recent years) than those in spring (~750 m). Because the autumn series is not spatially complete over the designated stock area, spring surveys are used as the primary estimator of abundance and biomass trends for this stock. However, autumn indices are still considered in assessments of this stock, because this survey is conducted when a greater proportion of Thorny Skate is available to survey trawl gear (Simpson et al. 2011). During autumn, Thorny Skates are concentrated on the shelf; whereas in spring, part of this population has moved to the shelf edge, and a proportion apparently moves outside of the spring survey area (Kulka et al. 2004). Additional causes of variation in autumn survey coverage are discussed in detail by Brodie and Stansbury (2007), and Healey and Brodie (2009).

Indices of relative abundance and biomass from Canadian autumn surveys in NAFO Div. 3LNO showed that mean catch rates in 1995-2011 had similar trends as observed for the spring time series: autumn indices have fluctuated at low levels (5-10 fish/tow; 7-18 kg/tow) with no general trend; except for a slight increase in catch rates in 2006-2008 (Fig. 7c). Historically, autumn abundance and biomass estimates remained stable at low levels in 1984-89 (i.e., only Div. 3L surveyed), annually averaging 79 million fish and 111 000 tons, respectively (i.e., Engel trawl data converted to Campelen-equivalents; Tables 4a,b; Fig. 8c). In 1990-94, abundance and biomass indices averaged 158 million fish (with 1990 peak of 214 million) and 170 000 tons (with 1990 peak of 260 000 t). In the Campelen survey trawl years of 1995-2011, these indices

annually averaged 77 million fish (with 2008 peak of 105 million) and 113 000 t (with 2008 peak of 187 000 t), respectively.

Considering Div. 3LNO separately, abundance and biomass indices for Div. 3L in 1983-88 averaged 84 million fish and 127 000 tons, respectively (Campelen-equivalents; Tables 4a,b). In 1990-94, Div. 3L indices averaged 78 million fish and 49 000 t; while Div. 3N and 3O averaged 36 million-44 million fish and 62 000 t. In 1995-2011, Div. 3L abundance and biomass indices continued to significantly decline to an annual average of 14 million fish and 17 000 t, respectively. Div. 3N indices moderately declined to an annual average of 28 million fish and 46 000 t; while abundance and biomass estimates remained relatively stable in Div. 3O during this period.

EU-SPAIN SURVEY

Spain initiated a survey in the NAFO Regulatory Area of Div. 3NO in 1995. Initially, the survey was carried out in spring with the C/V *Playa de Menduiña* using a Pedreira bottom trawl. Since 2001, the R/V *Vizconde de Eza* replaced the C/V *Playa de Menduíña* and a Campelen bottom trawl replaced Pedreira gear (González-Troncoso et al. 2012).

Biomass of Thorny Skate was estimated from EU-Spain surveys in the NRA of Div. 3NO in 1997-2011. The survey biomass index showed a consistent increase from 10 000 t in 1997 to a peak of 50 500 t in 2000 (Fig. 9). However, this index fluctuated annually since 2001; averaging 36 000 t in 2001-2006, and 21 500 t in 2007-2010; with a significant decline to 10 365 t in 2011: the lowest estimate in the time-series since 1998. A comparison of Canadian Campelen spring biomass indices to those of Spanish Div. 3NO surveys in 1997-2011 indicated similar overall trends; even though overall estimates were considerably higher in the former. It must be noted that the Canadian survey covers the entire area of Div. 3NO; whereas the Spanish survey is limited to the NAFO Regulatory Area of Div. 3NO.

DISTRIBUTION

In Subdiv. 3Ps and Div. 3LNO, the distribution of Thorny Skate has changed significantly since the 1980s. In the early 1980s, skates were widely distributed over the entire Grand Bank in moderate to high concentrations (Fig. 10a-c; Kulka and Miri 2007). By the late 1990s, much of the biomass was concentrated on the southwestern Grand Bank. In 2001-2005, the area of high concentration expanded northward and along the Bank edge. It is important to note that part of this population moves to the shelf edge in spring; thereby moving outside of the Canadian spring survey area (Kulka et al. 2004). However, Thorny Skates are concentrated on the shelf during autumn. In 2006-2012, Thorny Skate distribution continued to be concentrated in Subdiv. 3Ps, on the southwest Grand Bank in Div. 3O, as well as along the shelf edge of the bank in Div. 3LN (Fig. 10d,e).

SURVEY SIZE

Length frequency distribution of Thorny Skate captured in the Canadian Campelen spring surveys of Div. 3LNO and Subdiv. 3Ps from 1997-2012 ranged from 5-105 cm TL (Fig. 11). For most areas and years, a peak of young-of-the-year skates (YOY: 5-20 cm TL) was observed, and averaged 15 cm TL. It should also be noted that the highest percentage of YOY skates for this period was observed in 2009. A dominant peak of larger skates can be seen in spring survey data, with the following modes: 32 cm in 1997; 35 cm in 1998; 40 cm in 1999 and 2000; 44 cm in 2001; 46 cm in 2002; 48 cm in 2003; 55 cm in 2004 and 2005; 62 cm in 2006; 66 cm in 2007, 69 cm in 2008, 71 cm in 2009 and 2010, 72 cm in 2011, and 74 cm in 2012.

LIFE STAGES

Numbers of male and female Thorny Skate at length caught by Canadian Campelen spring surveys in Div. 3LNOPs during 1996-2012 were partitioned into YOY, immature, and mature (Spawning Stock Biomass: SSB) components (Fig. 12). Various life stages of Thorny Skate underwent different changes in abundance over time. In 1996-2012, Thorny Skate YOY appeared to be relatively stable in abundance; with an average of 5 578 000 males and 5 958 000 females. However, abundance estimates of male and female immature skates fluctuated along decreasing trends: from 20 540 000 males (1998) to 11 972 000 (2012); from 25 289 000 females (1999) to 16 017 000 (2012). Abundance estimates of mature skates fluctuated along an increasing trend: from 9 048 000 males (1997) to 22 169 000 (2012); from 4 968 000 females (1997) to 12 922 000 (2012).

The ratio of males to females in the sampled population remained relatively constant during 1996-2012; with some fluctuations in these three components (Fig. 13): YOY averaged 0.97 males to females; ratio of immature males to females was always smaller than 0.95 (0.73 average); while the mature abundance ratio was always greater than 1.07 (1.49 average). This pattern suggests some difference in the catchability of male and female Thorny Skates at different life stages; potentially due to differential migration into and out of the sampled area (Simpson et al. 2011).

A relationship between mature female abundance and Thorny Skate YOY from Canadian spring surveys of Div. 3LNOPs in 1985-95 (Engel trawl) and 1996-2011 (Campelen trawl) is illustrated in Figure 14. This pre-recruitment index followed an increasing trend in the Engel years; averaging 1.6. However, in the Campelen years, this index declined from 1.9 and 2.4 in 1996 and 1997 (respectively) to an average of 0.9 since 1998; with the lowest value of 0.45 occurring in 2003, and a recent peak of 1.6 in 2009. The latest index (2011) was 1.3. Note that Subdiv. 3Ps was not surveyed in 2006 and one-year-old skates in 2006 were caught only from the shallow (<104 m) portion of Div. 3NO due to incomplete survey coverage for that year. The pre-recruitment index has been above the Campelen average (1996-2011) for the past three years. However, it is unclear how this index relates to spawning stock recruitment.

INDEX OF FISHING MORTALITY

A relative Index of Fishing Mortality (Relative F = NAFO STATLANT-21A commercial landings/ Canadian spring survey biomass index) was calculated for Thorny Skate in Subdiv. 3Ps and Div. 3LNO for 1996-2011. Fishing Mortality Index for Subdiv. 3Ps since 1985 was relatively constant; remaining below 5% (except for 7% in 2001-2002; Fig. 15). Fishing Mortality in Div. 3LNO increased from the late 1980s to a peak of 29% in 1997; then stabilized at approximately 17% during 1998-2004. In 2005, this Index declined to 4%, and averaged 6% annually since then.

SUMMARY

Thorny Skates in NAFO Subdivision 3Ps and adjacent Divisions 3LNO are considered to constitute a single stock. Life history characteristics of Thorny Skate result in low inherent rates of population growth; thereby leading to low resilience to fishing mortality.

Thorny Skate distribution in the entire Div. 3LNOPs Thorny Skate stock area for 2007-2012 continued to be concentrated on the southwest Grand Bank, in Subdiv. 3Ps, and northward along the edge of the Bank in Div. 3LN. Biomass and abundance indices for Div. 3LNOPs underwent a decline during the late 1980s, and remain at relatively low levels. Although the pre-recruitment index followed an increasing trend during the Engel years, it declined in the Campelen

years; reaching its lowest value in 2003. This index was above the Campelen average (1996-2011) over 2009-11. However, it is unclear how this index relates to spawning stock recruitment.

Reported commercial landings of Thorny Skate in Subdiv. 3Ps have declined in recent years. In Subdivision 3Ps, the total reported landings averaged 1 308 t from 1994-2009. Landings during 2010 and 2011 averaged 808 t. From a peak of 18 277 t in 2000, total reported landings of skate by all countries in Div. 3LNO has declined. In 2005-2009, the average reported landings from Div. 3LNO was 5 091 t; which is approximately a third of the current TAC in Div. 3LNO. Discarding at sea of skate bycatch remains unreported by Canadian and other fishers; resulting in higher removals from the Thorny Skate stock than what available fisheries statistics indicate. As well, commercial skate landings remain unspeciated when reported by Canadian and other fishers to NAFO. Canadian Fisheries Observers do constitute a reliable source of skate commercial catch data by species; including discards at sea, however there is limited coverage in many fisheries.

An index of fishing mortality for Subdiv. 3Ps since 1985 was relatively constant; remaining below 5%. Fishing mortality in Div. 3LNO increased from the late 1980s to a peak of 29% in 1997; then stabilized at approximately 17% during 1998-2004. In 2005, the fishing mortality index declined to 4%, and averaged 6% annually since then.

The current TAC of 9 550 t for skates in Div. 3LNOPs (8 500 t in Div. 3LNO; 1 050 t in Subdiv. 3Ps) greatly exceeds average skate landings during a period when rebuilding of this stock has not occurred. It is recommended that annual total catch in Subdivision 3Ps should not exceed 870 tons (i.e., the average reported landings in 2009-2011), and that TAC limits be carefully monitored. Similar reductions in the TAC have occurred in the Division 3LNO portion of this stock.

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Table 1. Reported landings (tons) of unspeciated skates in NAFO Subdivision 3Ps, 1960-2011 (STATLANT-21A). Note that "Other" landings in 2009-2011 represent data from St. Pierre and Miquelon (EU-France; Joel Vigneau-IFREMER, pers. comm.).

Year	Canada	Other	Total
1960	0	11	11
1961	0	17	17
1962	0	11	11
1963	0	58	58
1964	0	145	145
1965	0	85	85
1966	0	126	126
1967	0	162	162
1968	86	67	153
1969	0	353	353
1970	35	229	264
1971	303	213	516
1972	8	184	192
1973	7	231	238
1974	122	641	763
1975	9	490	499
1976	91	230	321
1977	521	360	881
1978	454	256	710
1979	545	121	666
1980	554	609	1,163
1981	558	520	1,078
1982	117	395	512
1983	0	516	516
1984	21	602	623
1985	21	944	965
1986	7	1,576	1,583
1987	52	787	839
1988	2	781	783
1989	0	1,685	1,685
1990	5	549	554
1991	1	639	640
1992	13	46	59
1993	22	11	33
1994	1,566	3	1,569
1995	1,866	4	1,870
1996	603	2	605
1997	829	3	832
1998	1,251	6	1,257
1999	1,102	4	1,106
2000	935	21	956
2001	1,769	39	1,808
2002	1,413	238	1,651
2003	1,705	82	1,787
2004	1,190	87	1,277
2005	967	15	982
2006	910	78	988
2007	1,347	491	1,838
2008	763	633	1,395
2009	645	354	999
2010	342	529	871
2011	517	228	745

Table 2. Landings (tons) of unspeciated skates in NAFO Div. 3LNO, 1960-2011 (STATLANT-21A).

Year	Canada	Other	Total
1960	0	73	73
1961	0	119	119
1962	0	99	99
1963	0	65	65
1964	0	145	145
1965	17	199	216
1966	75	347	422
1967	212	188	400
1968	128	31	159
1969	68	1,123	1,191
1970	99	539	638
1971	125	77	202
1972	64	487	551
1973	10	413	423
1974	638	1,690	2,328
1975	180	2,535	2,715
1976	260	1,006	1,266
1977	551	1,266	1,817
1978	816	1,015	1,831
1979	382	657	1,039
1980	351	1,027	1,378
1981	244	1,467	1,711
1982	52	756	808
1983	4	1,277	1,281
1984	0	2,013	2,013
1985	9	10,390	10,399
1986	52	14,277	14,329
1987	195	18,301	18,496
1988	91	18,675	18,766
1989	15	14,222	14,237

Year	Canada	Other	Total
1990	44	14,726	14,770
1991	18	28,390	28,408
1992	78	5,059	5,137
1993	78	5,992	6,070
1994	1,554	6,601	8,155
1995	2,412	4,912	7,324
1996	1,314	4,804	6,118
1997	2,165	9,903	12,068
1998	1,013	8,501	9,514
1999	1,081	10,864	11,945
2000	498	17,779	18,277
2001	354	14,507	14,861
2002	1,107	10,648	11,755
2003	671	13,592	14,263
2004	352	11,476	11,828
2005	685	2,853	3,538
2006	248	5,255	5,504
2007	101	6,110	6,211
2008	243	6,867	7,110
2009	435	5,286	5,721
2010	50	5,314	5,364
2011	68	5,323	5,391

Table 3a. Abundance of Thorny Skate from Canadian spring research vessel surveys in Div. 3LNOPs, 1971-2012. Surveys were conducted with a Yankee bottom trawl (1971-82; data unconverted), an Engel trawl (1983-spring 1995; data converted to Campelen-equivalents), and a Campelen trawl (spring 1996-2012). Spring surveys: NAFO Subdiv. 3Ps was not surveyed in 1971, 2006; NAFO Div. 3O was not surveyed in 1972, 1974, 1983; and NAFO Div. 3N was not surveyed in 1983. Note that deep strata in Div. 3NO were not surveyed in spring 2006.

Abundance (thousands)					
Year	3L	3N	3O	3Ps	3LNOPs
Yankee Series - Unconverted					
1971	11,533	3,921			15,454
1972	11,037	15,634		5,615	32,285
1973	12,114	11,033	12,830	6,822	42,800
1974	26,621	11,627		11,136	49,383
1975	24,762	8,273	12,183	1,654	46,871
1976	28,294	21,419	28,595	19,118	97,427
1977	25,240	16,375	7,518	8,840	57,973
1978	21,879	10,117	7,578	11,911	51,485
1979	23,370	13,859	7,496	8,310	53,034
1980	19,206	15,847	16,788	12,200	64,041
1981	33,223	9,694	5,912	12,195	61,024
1982	21,391	23,623	11,055	3,562	59,632
Engel Series = Campelen Equivalents					
1983				29,719	29,719
1984	7,574	25,226	24,615	9,417	66,832
1985	63,081	45,278	50,123	55,214	213,697
1986	51,231	53,394	21,134	36,153	161,911
1987	39,151	33,538	34,041	28,113	134,844
1988	35,030	26,474	42,991	19,043	123,538
1989	40,350	30,030	17,678	25,863	113,921
1990	43,938	71,656	40,118	21,344	177,055
1991	34,779	44,549	35,195	50,254	164,777
1992	37,475	20,645	35,567	21,510	115,198
1993	27,765	17,068	15,025	21,580	81,437
1994	15,999	17,565	19,105	19,221	71,891
1995	9,320	7,017	26,781	19,493	62,611
Campelen Series					
1996	10,418	10,636	22,731	25,591	69,376
1997	6,804	13,554	25,635	18,379	64,372
1998	7,764	10,140	34,130	22,781	74,815
1999	8,263	15,967	36,042	20,212	80,484
2000	12,512	16,027	28,525	18,574	75,638
2001	8,521	16,276	33,321	17,606	75,724
2002	5,920	8,469	32,902	17,560	64,851
2003	6,737	9,645	34,734	24,615	75,732
2004	4,762	8,925	21,153	24,256	59,095
2005	11,011	15,986	26,621	26,399	80,016
2006	8,450	23,618	17,778		49,846
2007	11,357	24,065	23,317	27,690	86,430
2008	10,572	14,477	22,738	31,239	79,027
2009	5,810	15,560	18,132	19,128	58,629
2010	10,964	20,714	32,747	26,447	90,871
2011	7,226	12,731	31,576	23,409	74,941
2012	13,342	15,866	24,268	21,848	75,324

Table 3b. Biomass of Thorny Skate from Canadian spring research vessel surveys in Div. 3LNOPs, 1971-2012. Surveys were conducted with a Yankee bottom trawl (1971-82; data unconverted), an Engel trawl (1983-spring 1995; data converted to Campelen-equivalents), and a Campelen trawl (spring 1996-2012). Spring surveys: NAFO Subdiv. 3Ps was not surveyed in 1971, 2006; NAFO Div. 3O was not surveyed in 1972, 1974, 1983; and NAFO Div. 3N was not surveyed in 1983. Note that deep strata in Div. 3NO were not surveyed in spring 2006.

Biomass (tonnes)					
Year	3L	3N	3O	3Ps	3LNOPs
Yankee Series - Unconverted					
1971	35,100	11,307			46,408
1972	23,391	36,084		16,422	75,897
1973	17,993	27,241	23,288	13,417	81,940
1974	40,252	21,823		22,428	84,503
1975	31,191	21,579	25,328	5,719	83,817
1976	40,242	39,416	80,235	29,506	189,399
1977	63,601	44,092	19,632	12,326	139,651
1978	37,944	16,394	17,803	10,266	82,407
1979	44,377	23,877	19,820	10,094	98,168
1980	41,247	26,141	21,488	21,149	110,025
1981	55,274	17,293	12,311	11,450	96,329
1982	37,768	30,161	22,868	7,363	98,161
Engel Series = Campelen Equivalents					
1983				34,950	34,950
1984	17,269	57,720	61,026	20,318	156,333
1985	102,351	86,438	110,322	36,954	336,065
1986	69,864	110,325	46,634	47,728	274,551
1987	82,037	60,535	51,007	40,697	234,276
1988	70,143	49,686	87,375	29,993	237,197
1989	73,291	49,142	40,172	44,271	206,875
1990	45,312	47,479	61,946	24,264	179,002
1991	22,197	28,925	99,003	61,534	211,659
1992	11,945	23,047	57,929	38,693	131,615
1993	8,546	18,550	35,113	16,256	78,465
1994	3,920	10,193	28,874	16,539	59,526
1995	2,798	2,824	32,323	24,924	62,869
Campelen Series					
1996	4,993	11,010	35,529	21,851	73,382
1997	3,969	9,703	28,293	20,705	62,669
1998	5,807	13,186	42,351	28,629	89,972
1999	7,266	26,254	54,045	32,062	119,626
2000	14,011	27,861	40,917	22,528	105,317
2001	10,383	29,197	59,078	24,566	123,223
2002	8,580	13,986	38,025	22,127	82,718
2003	8,411	18,216	49,707	37,072	113,406
2004	7,806	20,425	39,740	38,354	106,325
2005	19,266	33,757	46,515	32,702	132,240
2006	16,193	56,698	25,252		98,143
2007	25,044	54,188	48,369	37,469	165,071
2008	23,344	32,196	42,220	38,509	136,270
2009	7,765	29,478	52,619	27,788	117,651
2010	14,944	34,303	68,435	39,968	157,650
2011	10,046	21,239	57,020	44,310	132,615
2012	14,828	38,621	53,443	33,699	140,592

Table 4a. Abundance of Thorny Skate from Canadian autumn research vessel surveys in Div. 3LNO, 1981-2011. Surveys were conducted with an Engel trawl (1978-94), and a Campelen trawl (1995-2011). Due to vessels' mechanical difficulties, deep strata of Div. 3NO were not surveyed in 2003, 2004, 2006, 2008.

Abundance (thousands)				
Year	Div. 3L	Div. 3N	Div. 3O	3LNO
Engel Series = Campelen Equivalents				
1983	103,303			103,303
1984	70,979			70,979
1985	86,070			86,070
1986	75,424			75,424
1987	80,879			80,879
1988	86,633			86,633
1989	76,793			76,793
1990	116,758	43,855	53,191	213,803
1991	73,576	61,128	29,680	164,384
1992	94,058	33,854	24,675	152,587
1993	61,501	31,073	41,382	133,957
1994	44,205	50,141	30,748	125,094
Campelen Series				
1995	23,299	37,322	30,582	91,203
1996	23,483	22,694	45,145	91,321
1997	13,448	30,540	50,047	94,035
1998	8,917	21,132	29,785	59,834
1999	10,448	25,116	31,847	67,411
2000	12,536	31,419	39,918	83,873
2001	12,655	21,352	42,095	76,103
2002	7,541	30,925	24,488	62,954
2003	9,363	19,203	34,556	63,121
2004	6,369	21,068	32,343	59,780
2005	11,346	20,027	30,553	61,927
2006	8,888	23,211	27,688	59,787
2007	13,372	36,453	29,768	79,594
2008	15,856	48,011	40,944	104,811
2009	17,145	28,813	42,965	88,922
2010	18,429	30,859	28,137	77,426
2011	16,841	26,907	36,711	80,459

Table 4b. Biomass of Thorny Skate from Canadian autumn research vessel surveys in Div. 3LNO, 1981-2011. Surveys were conducted with an Engel trawl (1978-94), and a Campelen trawl (1995-2011). Due to vessels' mechanical difficulties, deep strata of Div. 3NO were not surveyed in 2003, 2004, 2006, 2008.

Biomass (tonnes)				
Year	Div. 3L	Div. 3N	Div. 3O	3LNO
Engel Series = Campelen Equivalents				
1983	165,500			165,500
1984	149,061			149,061
1985	141,054			141,054
1986	113,170			113,170
1987	87,843			87,843
1988	107,910			107,910
1989	67,877			67,877
1990	95,586	67,459	97,496	260,540
1991	52,655	103,959	75,526	232,141
1992	40,289	52,980	42,383	135,652
1993	24,096	35,528	64,294	123,918
1994	16,212	50,950	31,929	99,090
Campelen Series				
1995	11,306	40,775	44,653	96,734
1996	14,459	28,629	36,969	80,057
1997	7,534	43,075	58,160	108,770
1998	9,205	34,279	39,280	82,764
1999	13,614	32,609	42,608	88,831
2000	17,722	61,202	40,861	119,786
2001	16,420	34,311	62,156	112,886
2002	11,068	52,855	40,593	104,517
2003	14,463	36,829	46,123	97,416
2004	11,327	45,678	26,361	83,366
2005	20,107	37,442	61,595	119,143
2006	18,610	54,372	50,605	123,587
2007	30,089	70,198	56,976	157,263
2008	27,182	83,861	75,892	186,935
2009	22,848	40,801	63,200	126,849
2010	21,051	27,270	54,857	103,178
2011	16,150	51,955	69,053	137,158

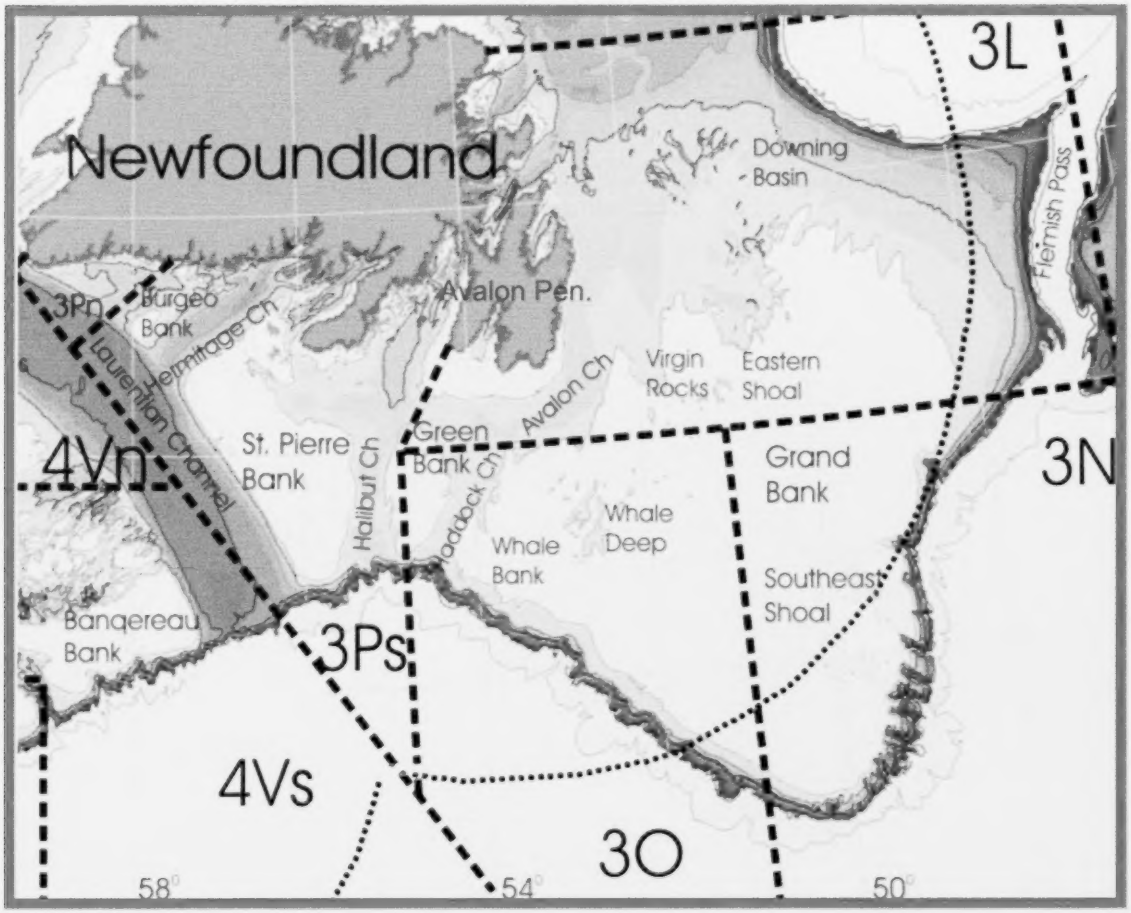

Figure 1. Map of NAFO Subdivision 3Ps and Divisions 3LNO in relation to Canada's 200-mile limit.

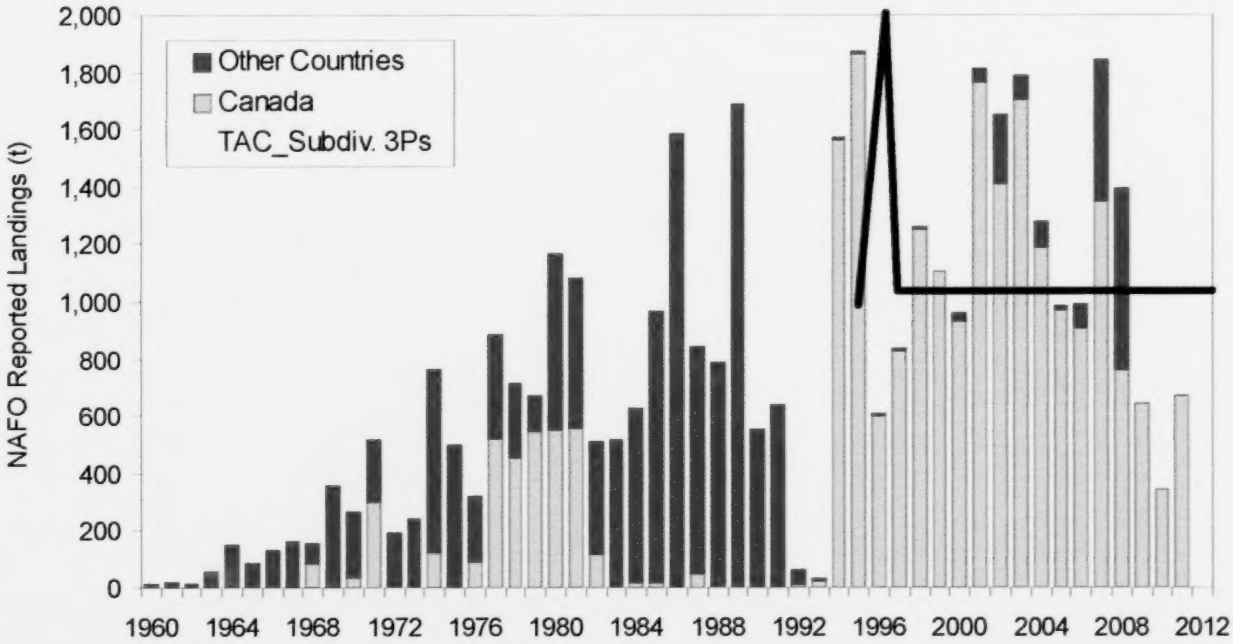

Figure 2. NAFO-reported landings (tons) of Thorny Skate by Canada and other countries in NAFO Subdiv. 3Ps in 1960-2011 (STATLANT-21A). Data do not include discards at sea. Total Allowable Catch (TAC) in Subdiv. 3Ps is set by Canada's Department of Fisheries and Oceans (DFO).

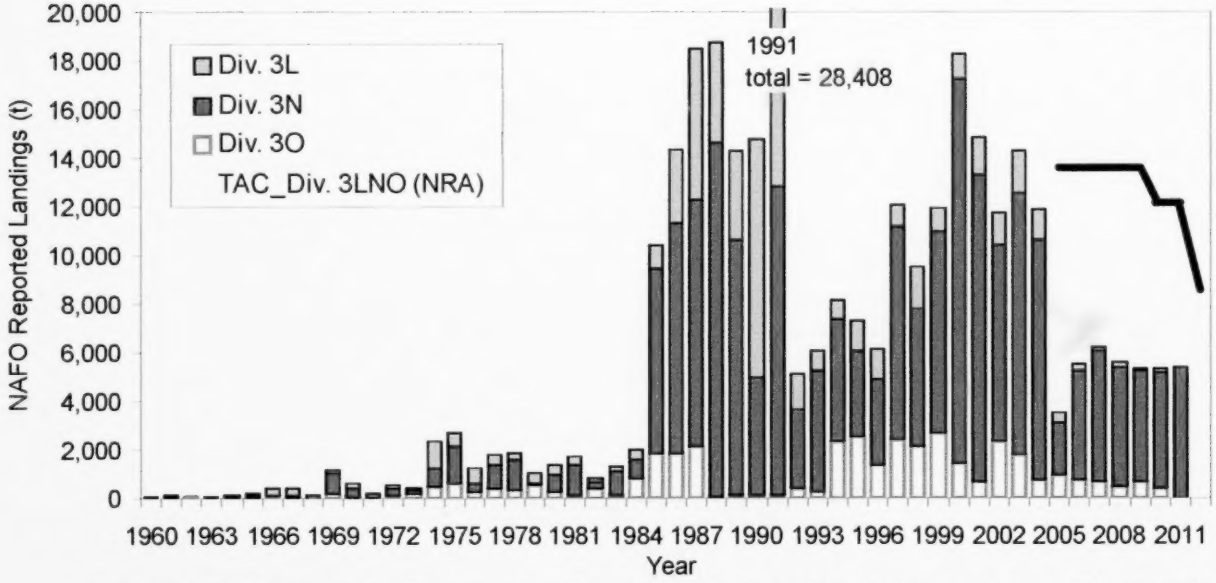

Figure 4. NAFO-reported landings (tons) of Thorny Skate by Canada and other countries in Div. 3LNO in 1960-2011 (STATLANT-21A). Data do not include discards at sea. Total Allowable Catch (TAC) in the NAFO Regulatory Area (NRA) of Div. 3LNO is set by the Northwest Atlantic Fisheries Organization (NAFO).

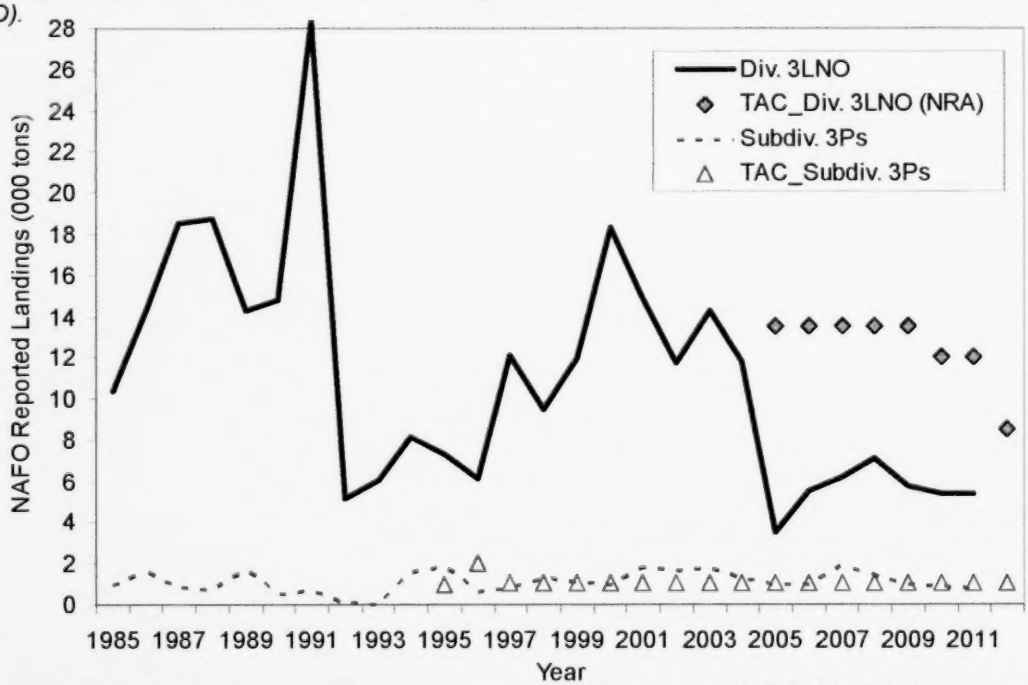

Figure 5. Total reported landings of Thorny Skate and Total Allowable Catch (TAC) in Subdiv. 3Ps and Div. 3LNO, 1985-2011. Data are NAFO-reported landings (STATLANT-21A), and do not include discards at sea.

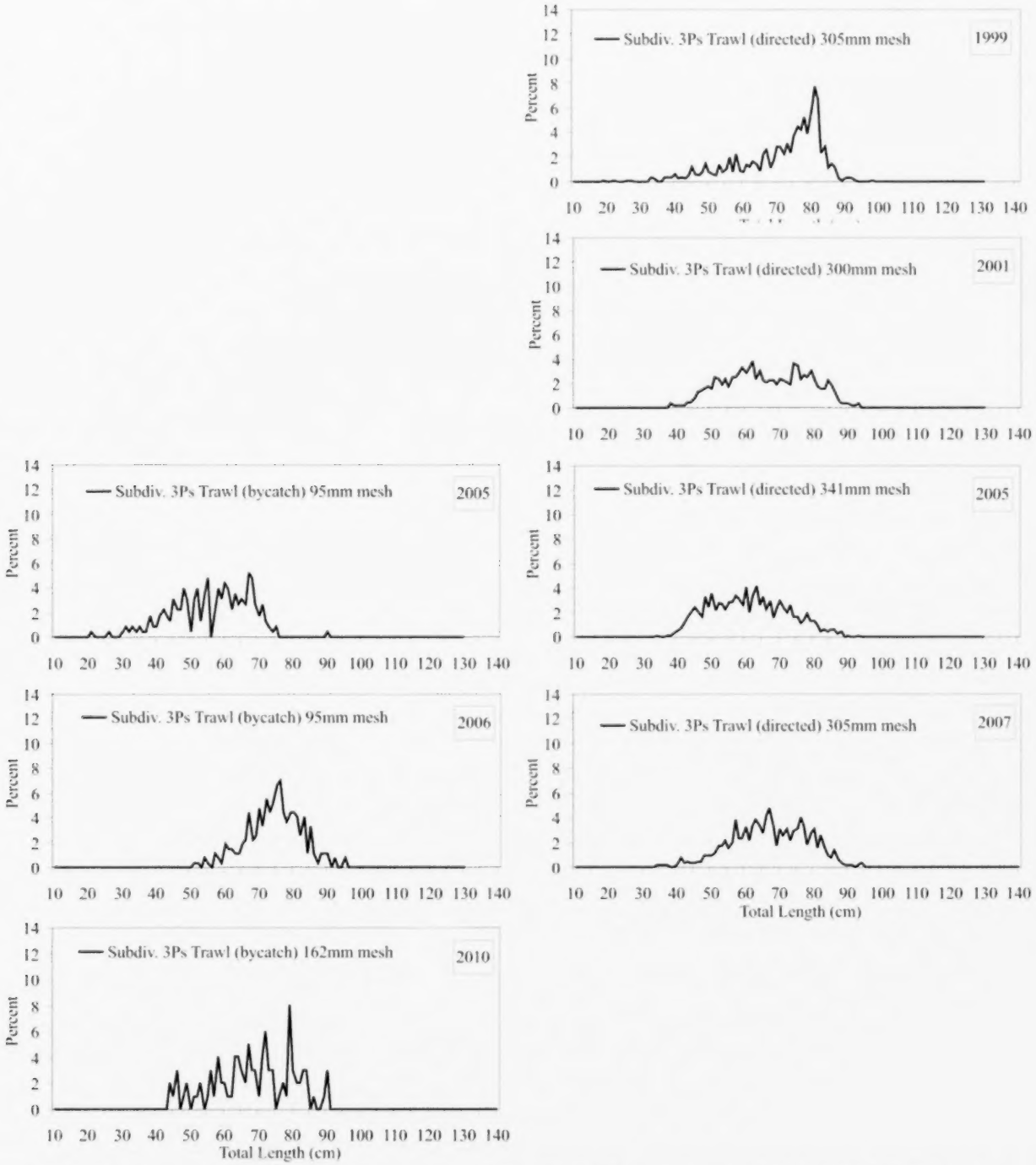

Figure 6a. Length distributions of Canadian commercial catches (sexes combined) in NAFO Subdiv. 3Ps for directed (right column) skate and bycatch (left column) bottom trawl fisheries, 1999-2010. Data are from Canadian Fisheries Observers. Note that Subdiv. 3Ps trawled skates were not sampled in 2011.

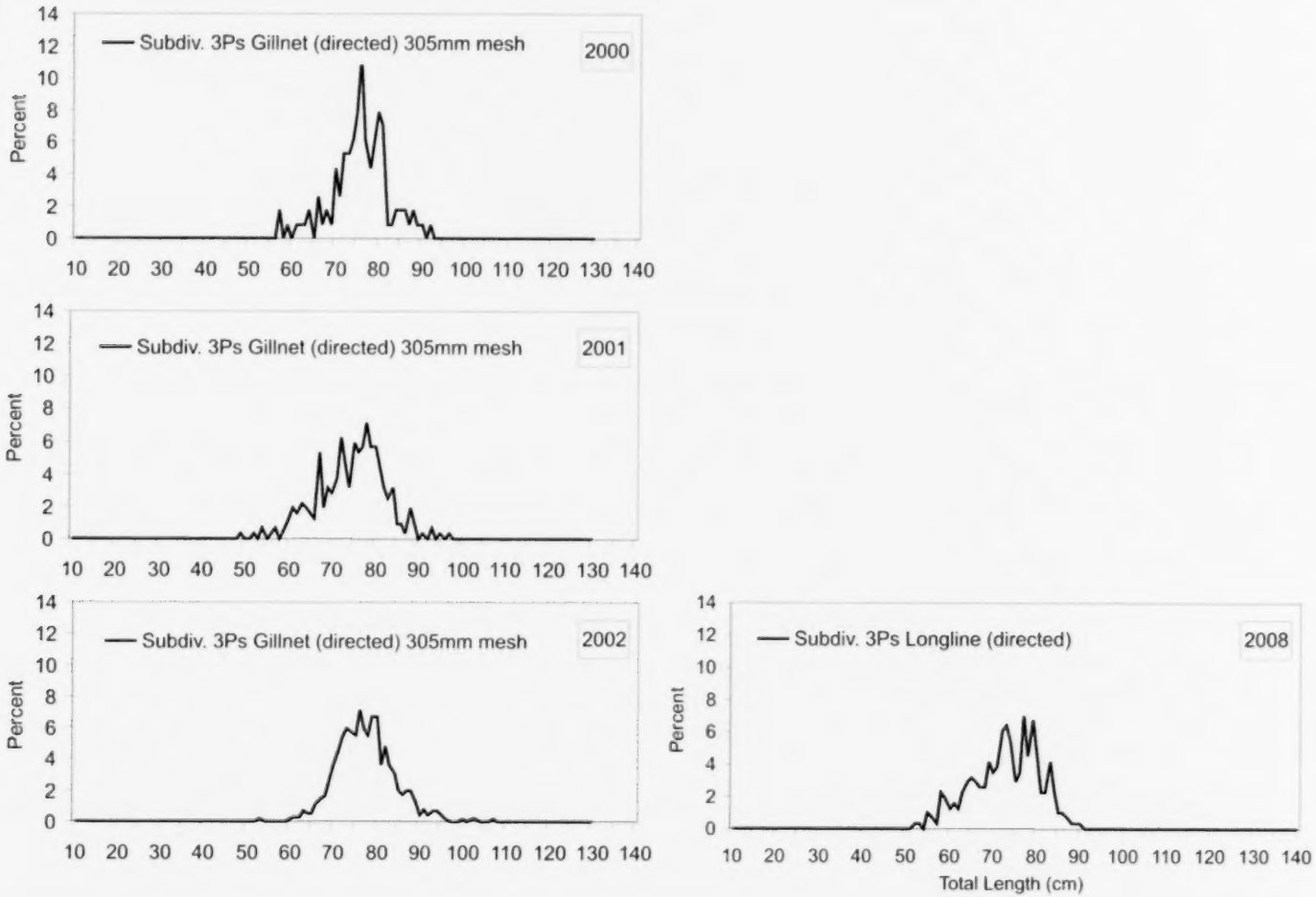

Figure 6b. Length distributions of Canadian commercial catches (sexes combined) in NAFO Subdiv. 3Ps for directed skate gillnet (left column) and longline (right column) fisheries, 2000-2008. Data are from Canadian Fisheries Observers. Note that Subdiv. 3Ps skates from these gears were not sampled in 2009-2011.

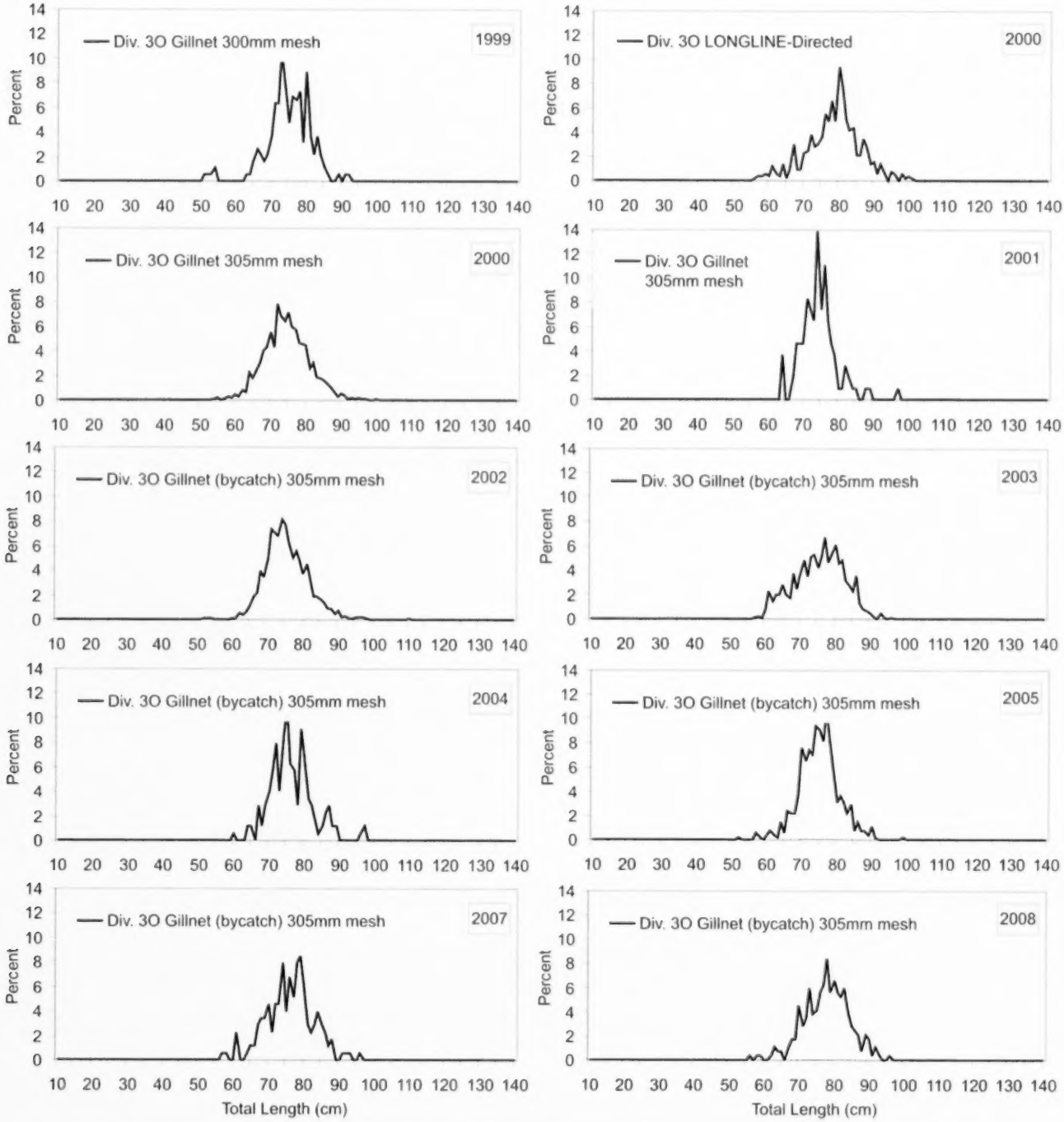

Figure 6c. Length distributions of Canadian commercial catches (sexes combined) in NAFO Div. 3O for monkfish-directed gillnet and skate-directed longline fisheries, 1999-2008. Data are from Canadian Fisheries Observers. Note that Div. 3O skates from these gears were not sampled in 2009-2011.

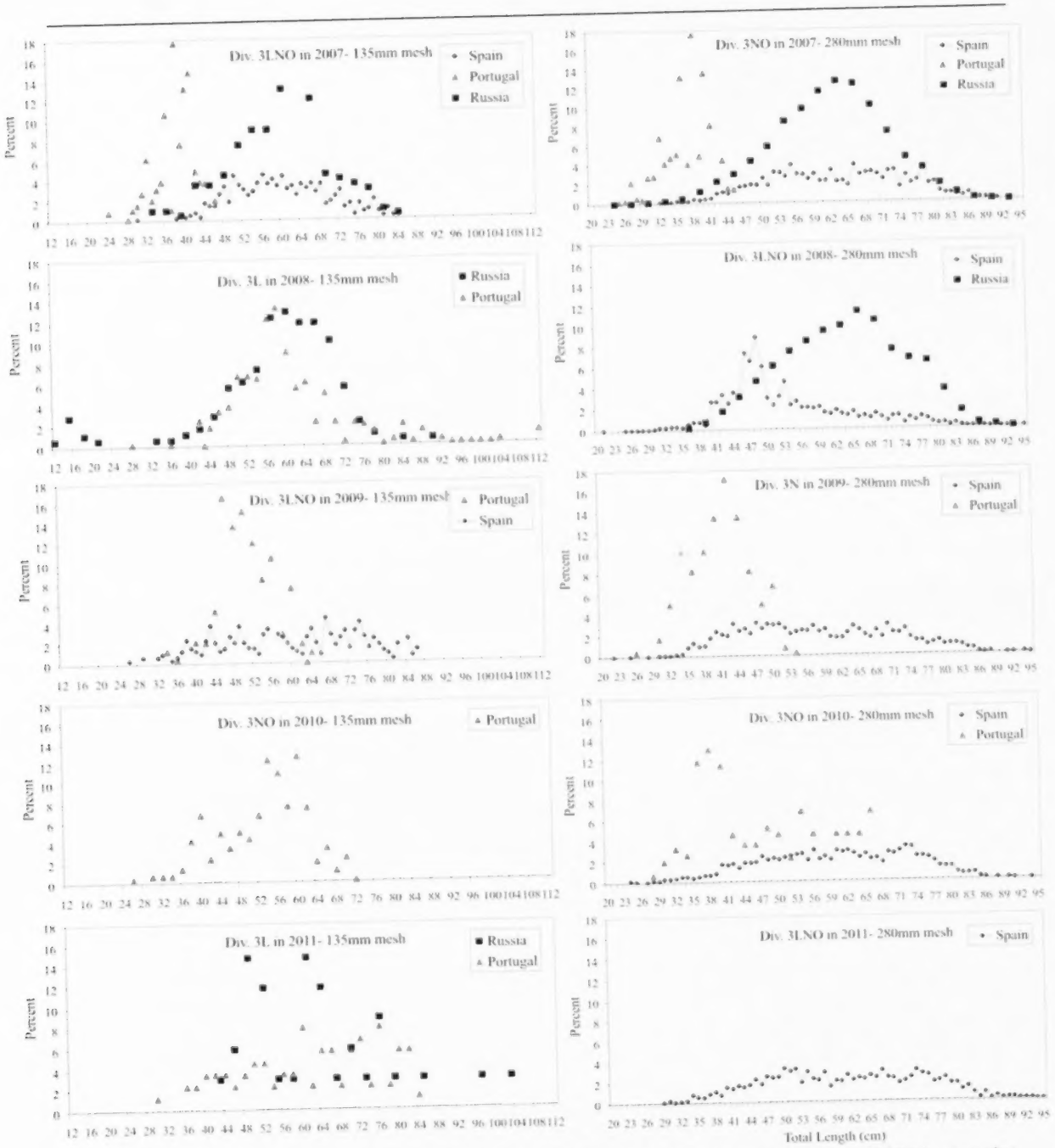

Figure 6d. Length distributions of commercial catches (sexes combined) in NAFO Div. 3LNO by country for directed skate (280 mm; right column) and bycatch (135 mm; left column) trawl fisheries, 2007-2011.

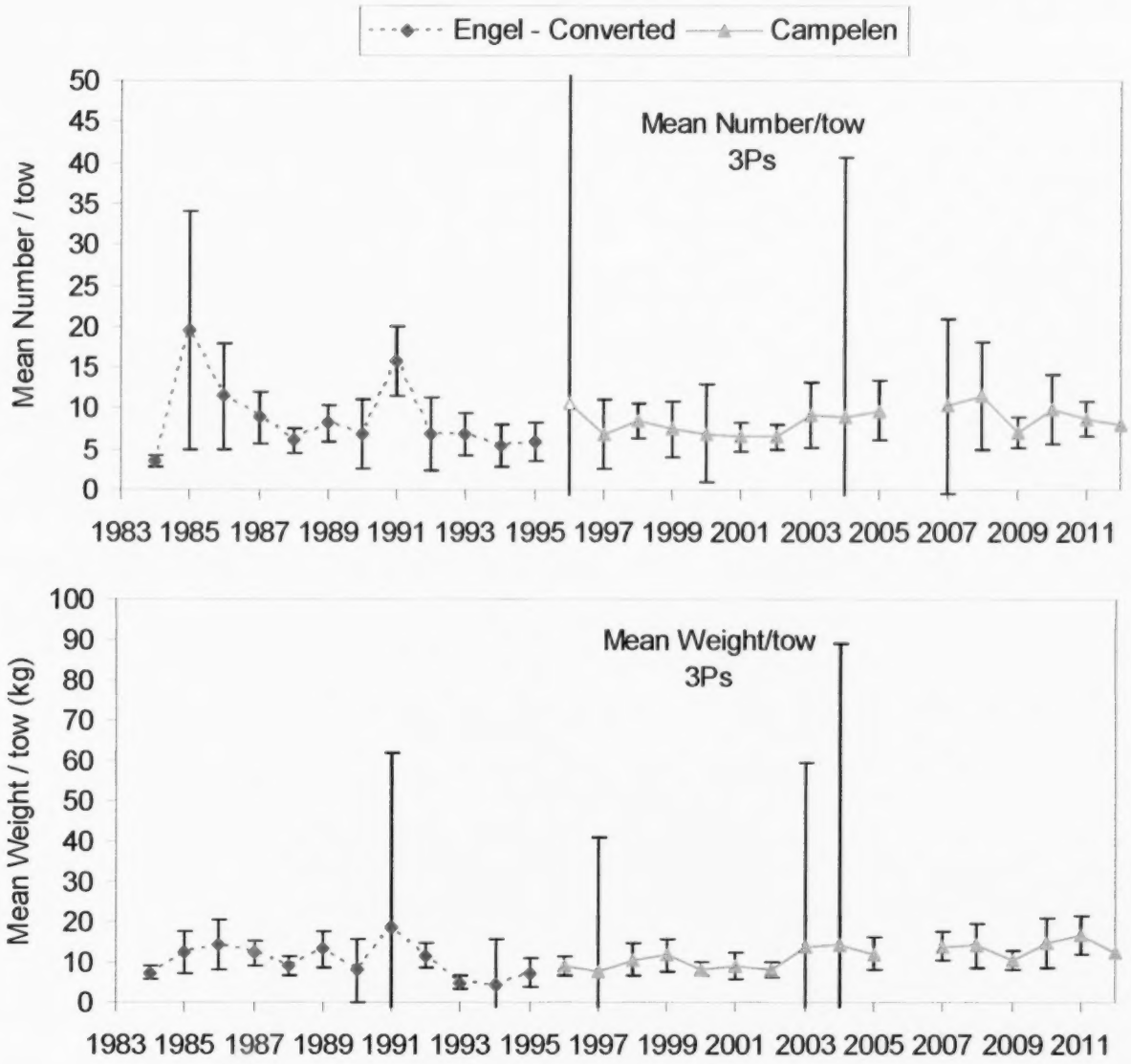

Figure 7a. Mean numbers and weights (kg) per tow (+/- 95% CI) of Thorny Skate from Canadian spring surveys in NAFO Subdiv. 3Ps, 1984-2012. Note that Subdiv. 3Ps was not surveyed in 2006, due to mechanical difficulties on Canadian research vessels. Hollow data points are associated with large Confidence Intervals.

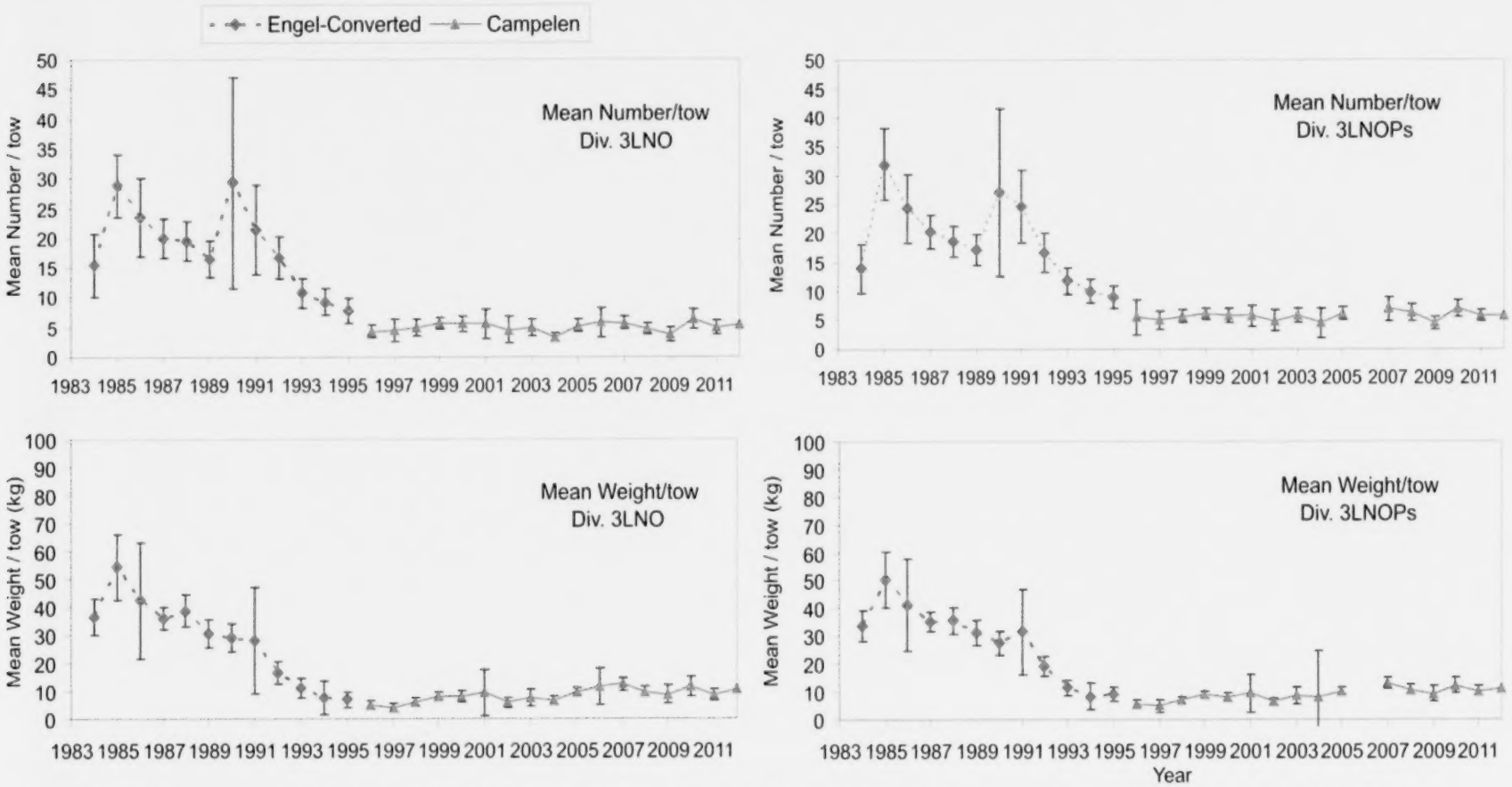

Figure 7b. Mean numbers and weights (kg) per tow (+/- 95% CI) of Thorny Skate from Canadian spring surveys in NAFO Div. 3LNO and 3LNOPs, 1984-2012. Note that Div. 3LNO were not surveyed in 1983; Subdiv. 3Ps was not surveyed in 2006; nor was the deeper portion (>103 m) of Div. 3NO in that year, due to mechanical difficulties on Canadian research vessels.

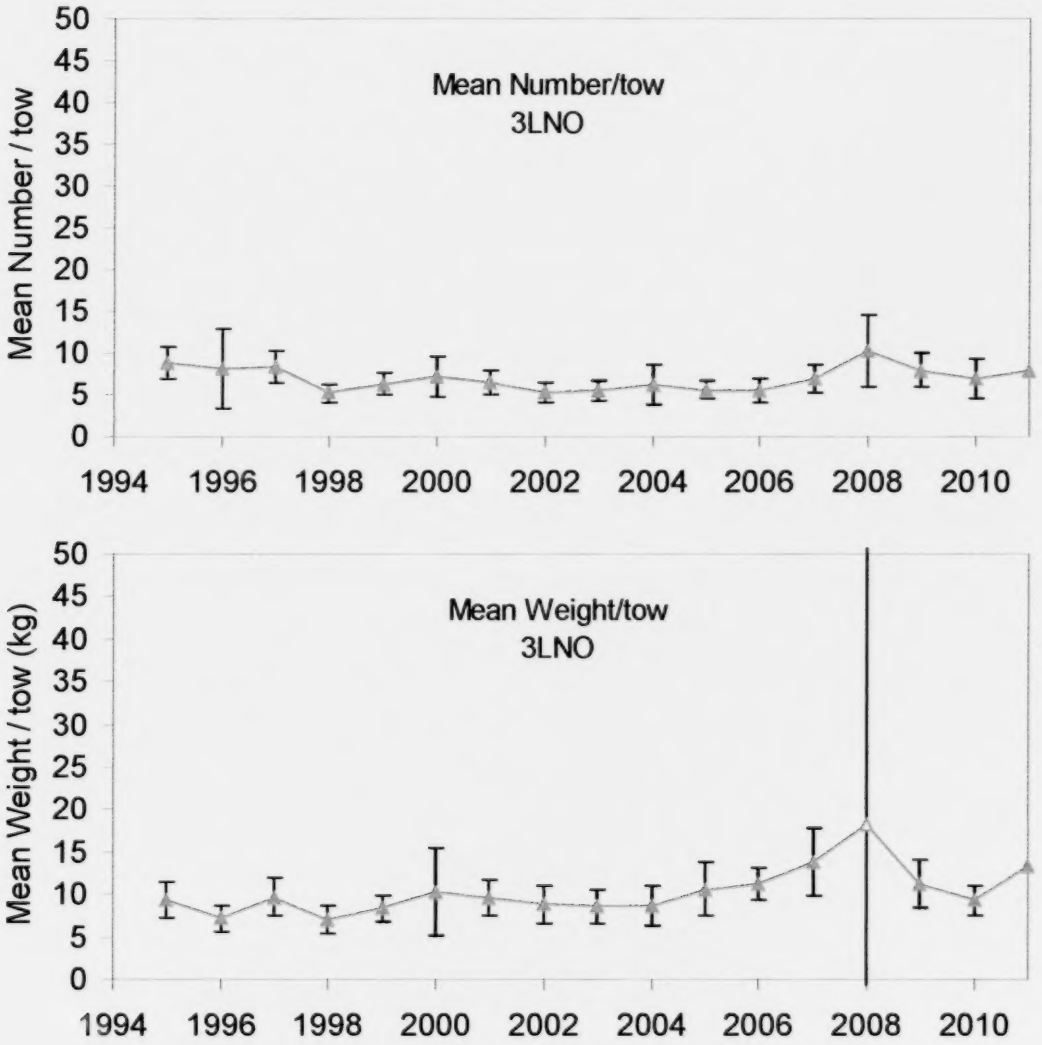

Figure 7c. Mean numbers and weights (kg) per tow (+/- 95% CI) of Thorny Skate from Canadian autumn surveys in NAFO Div. 3LNO, 1995-2011 Hollow data points are associated with large Confidence Intervals.

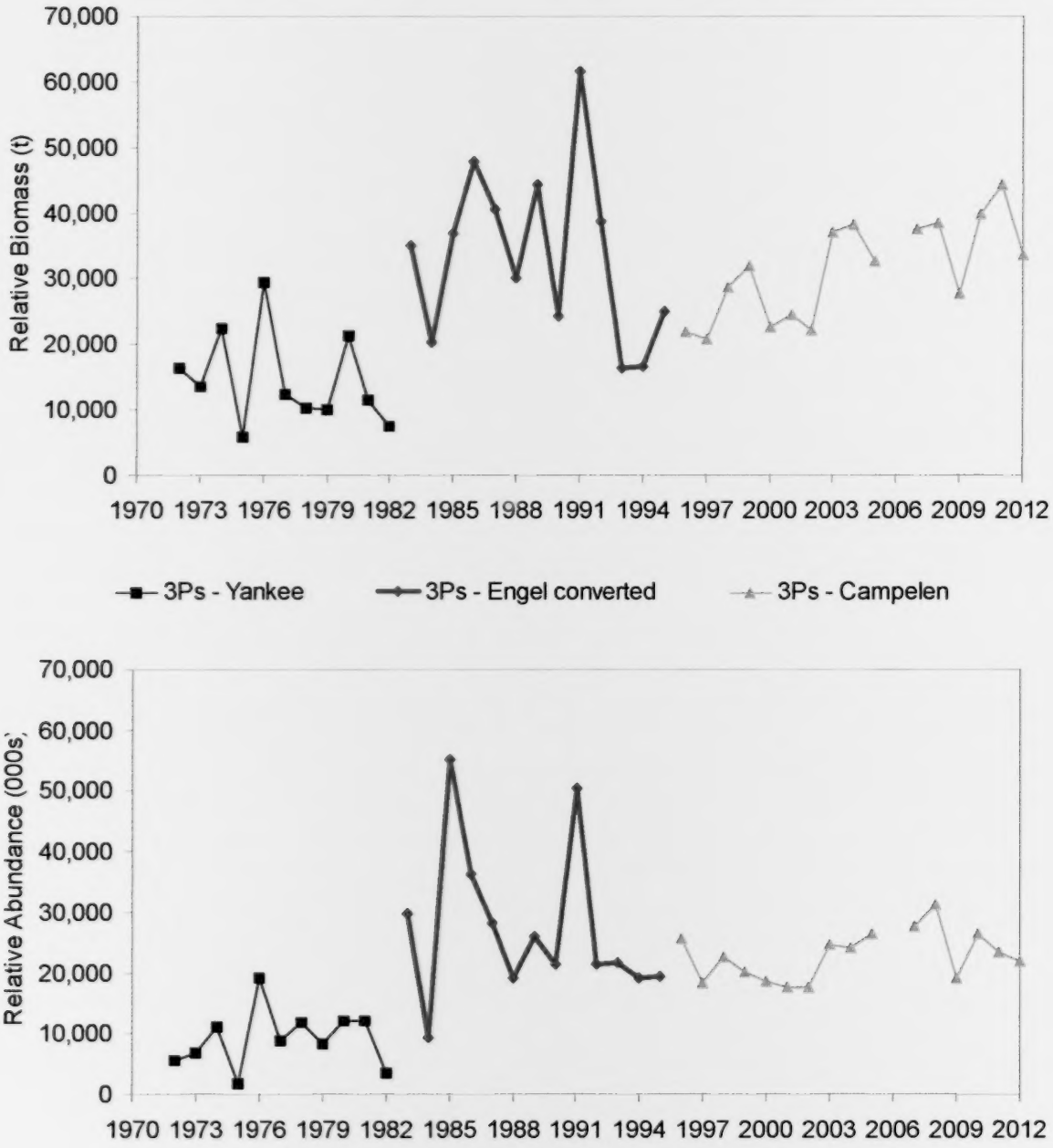

Figure 8a. Canadian spring research survey biomass and abundance indices for Thorny Skate in NAFO Subdivision 3Ps, 1972-2012. Note that Subdiv. 3Ps was not surveyed in 2006, due to mechanical difficulties on Canadian research vessels.

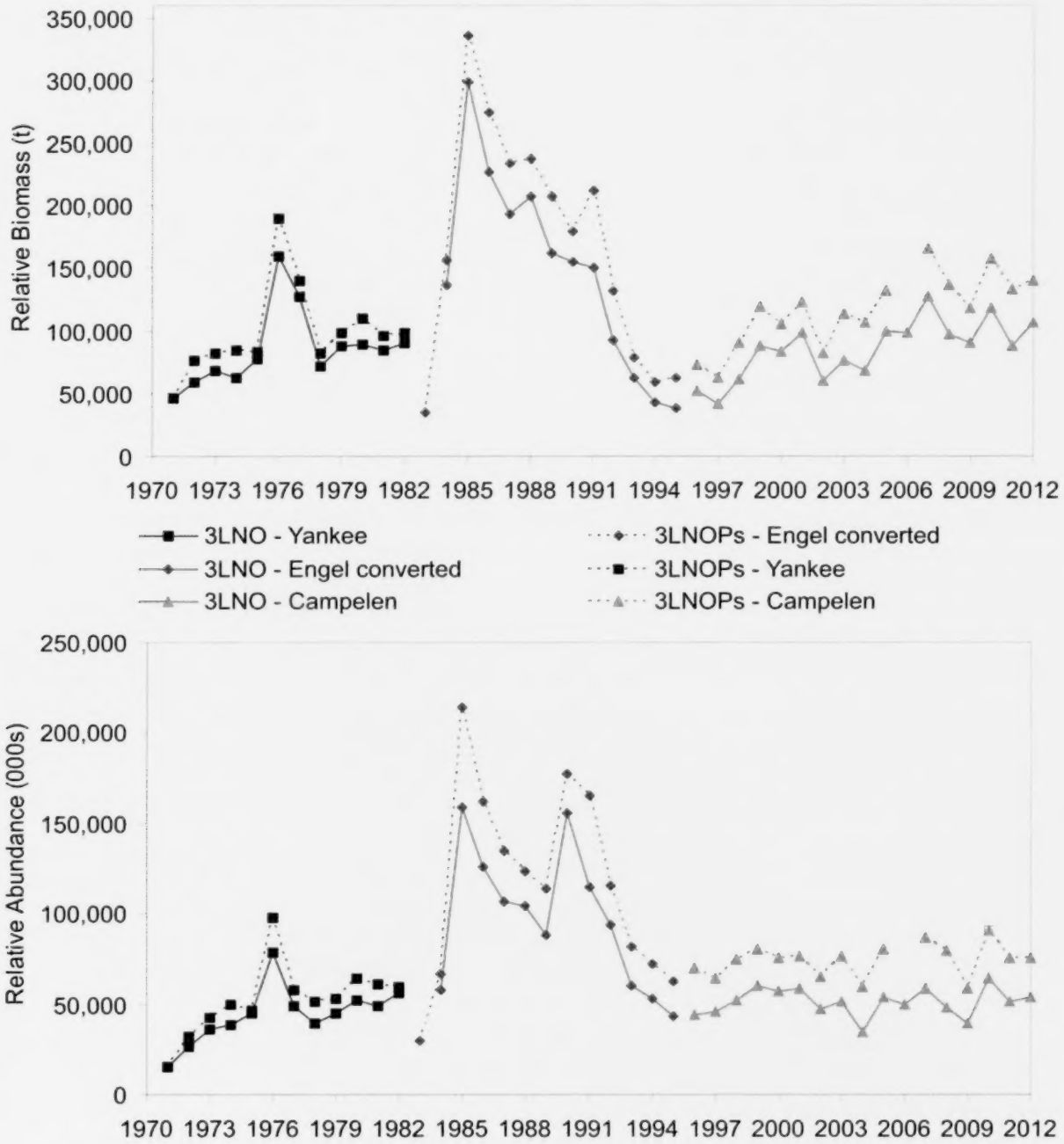

Figure 8b. Canadian spring research survey biomass and abundance indices for Thorny Skate in NAFO Div. 3LNO, and Subdivision 3Ps, 1971-2012. Note that Div. 3LNO were not surveyed in 1983; Subdiv. 3Ps was not surveyed in 2006; neither the deeper portion (>103 m) of Div. 3NO in that year, due to mechanical difficulties on Canadian research vessels.

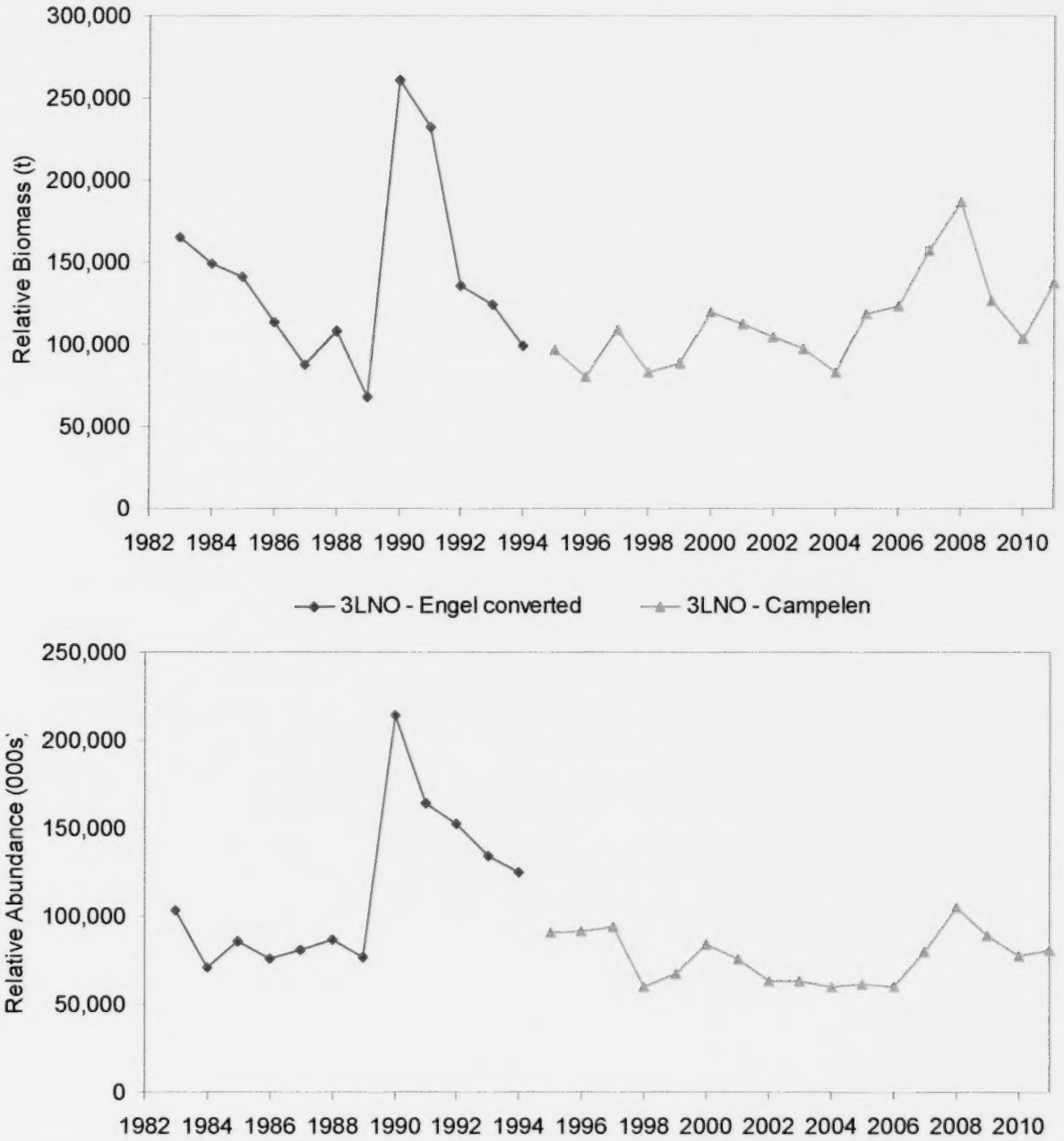

Figure 8c. Canadian autumn research survey biomass and abundance indices for Thorny Skate in NAFO Div. 3LNO, 1983-2011. Note that Div. 3L was surveyed in 1981-2011; Div. 3NO were surveyed in 1990-2011. Due to vessels' mechanical difficulties, deep strata of Div. 3NO were not surveyed in 2003, 2004, 2006, 2008.

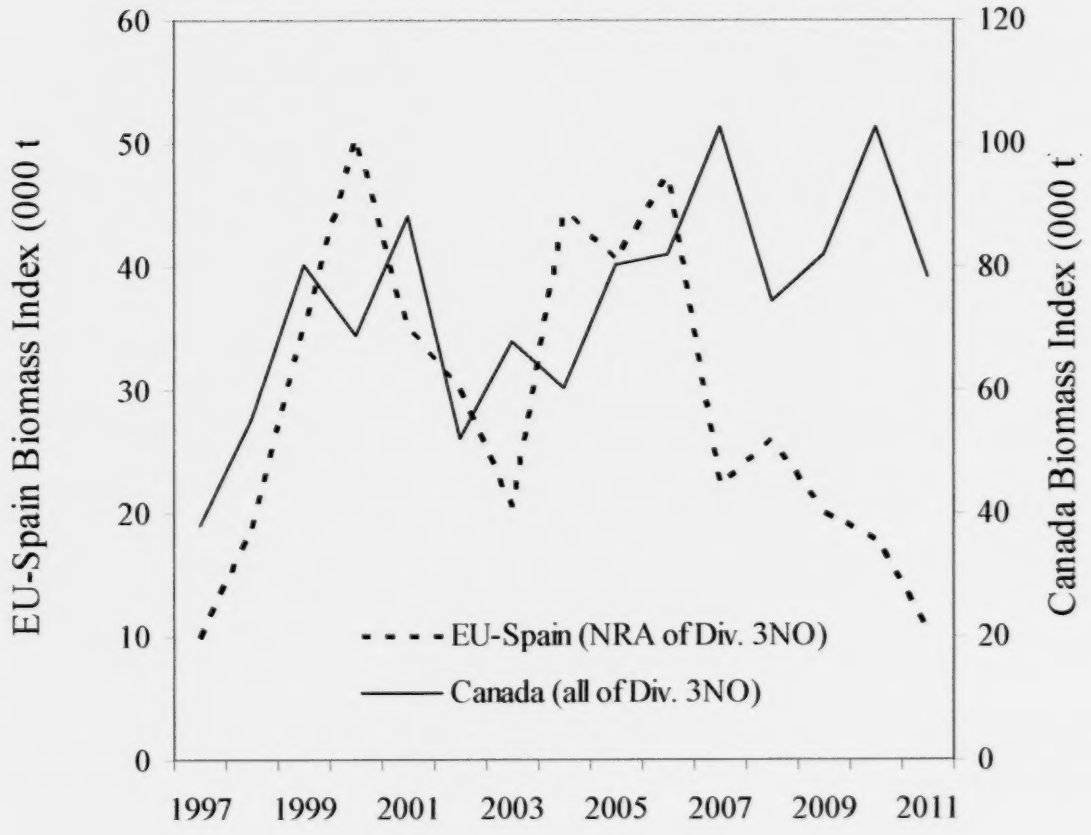

Figure 9. Comparison of Thorny Skate biomass indices in 1997-2011 from the Canadian Campelen spring survey in Div. 3NO and the Spanish Campelen spring survey in Div. 3NO. Note that Spanish surveys occur only in the NAFO Regulatory Area (NRA) of Div. 3NO.

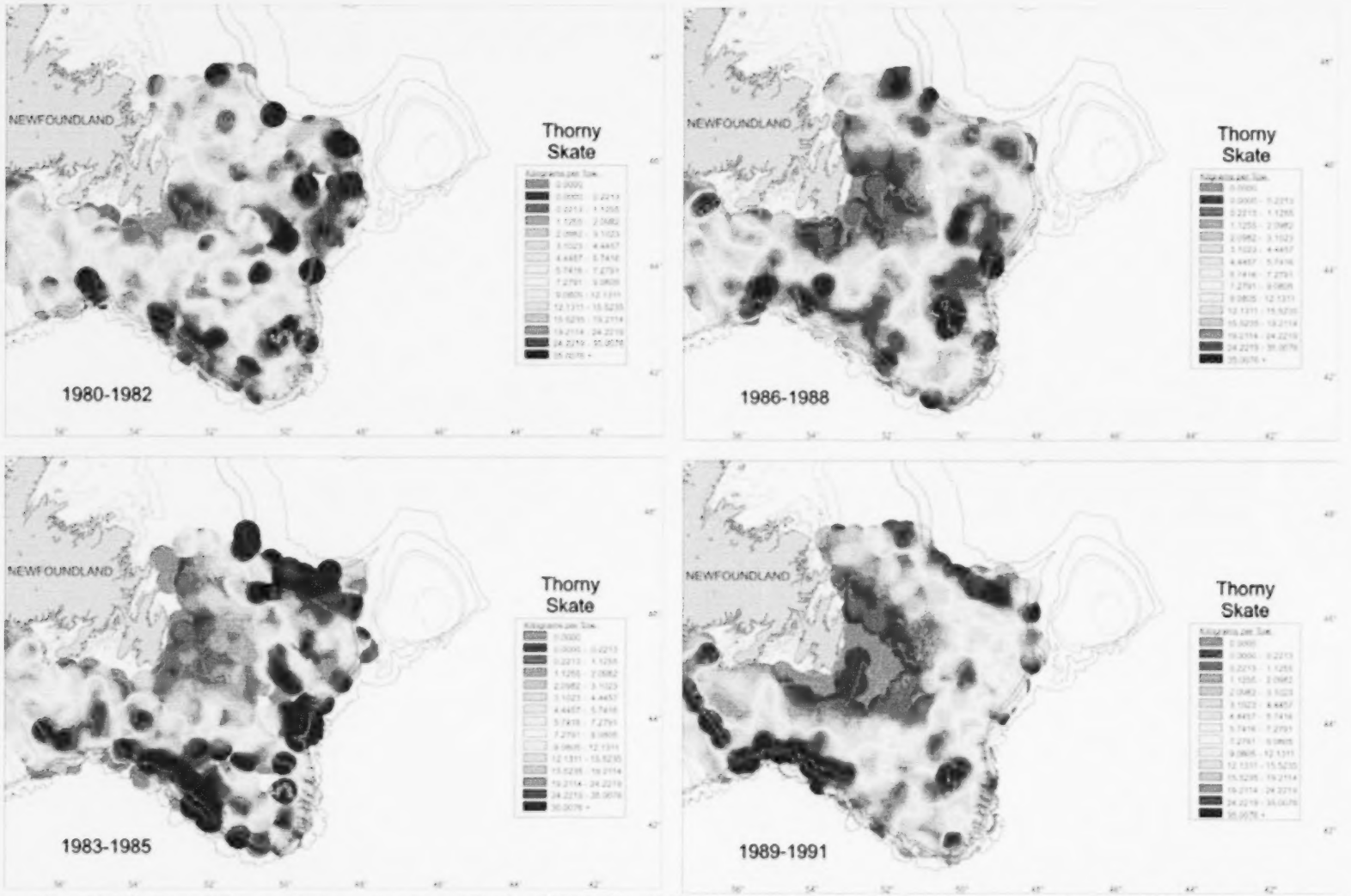

Figure 10a. Distribution of Thorny Skate on the Grand Banks (NAFO Div. 3LNOPs), based on Canadian spring surveys in 1980-1991. Green represents low catch rates (kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas. Maps taken from Kulka et al. (2004).

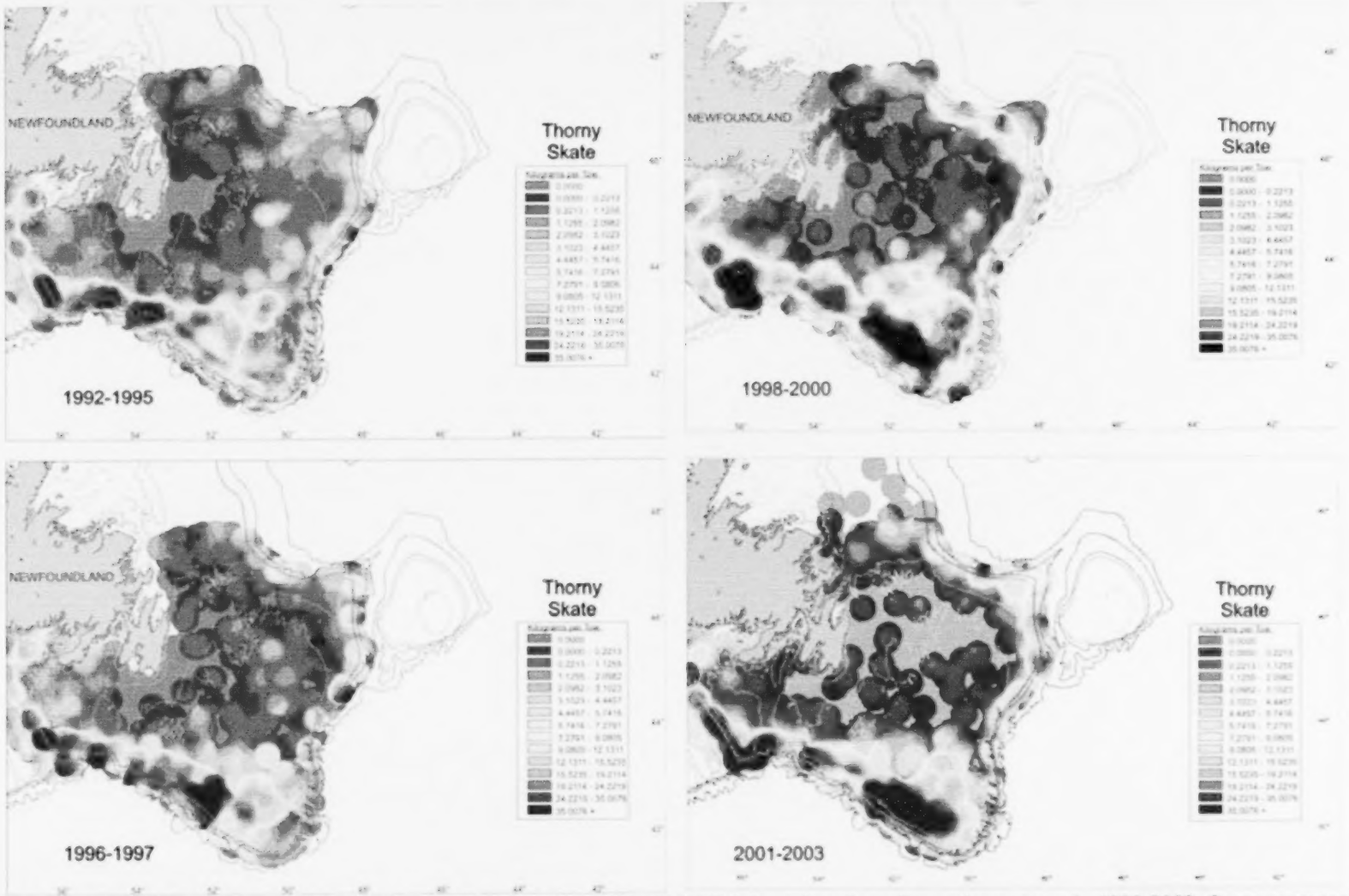

Figure 10b. Distribution of Thorny Skate on the Grand Banks (NAFO Div. 3LNOPs), based on Canadian spring surveys in 1992-2003. Green represents low catch rates (kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas. Maps taken from Kulka et al. (2004).

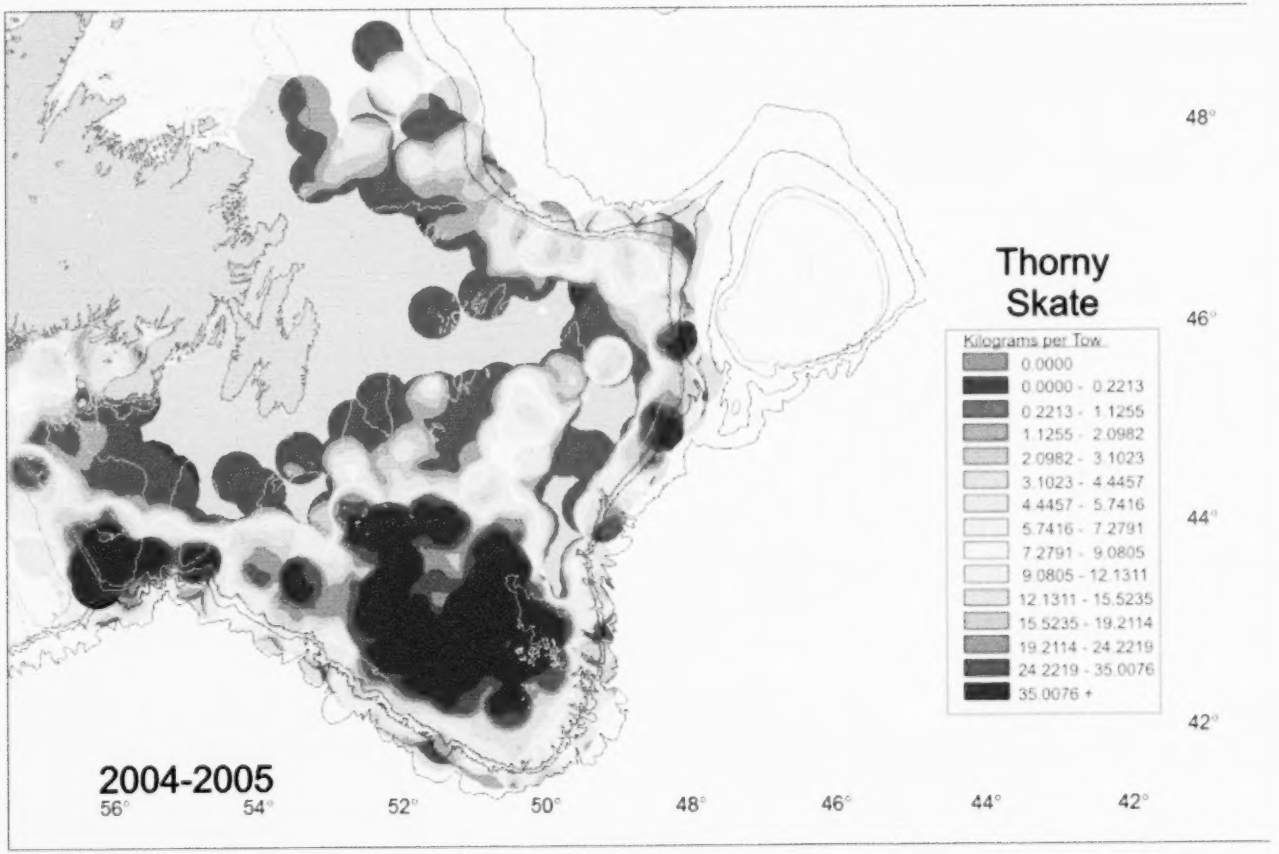

Figure 10c. Distribution of Thorny Skate on the Grand Banks (NAFO Div. 3LNOPs), based on Canadian spring surveys in 2004-2005. Green represents low catch rates (kg per tow). Red represents high catch rates. Grey denotes sampled areas with no skate catches. White depicts unsampled areas. Maps taken from Kulka et al. (2006).

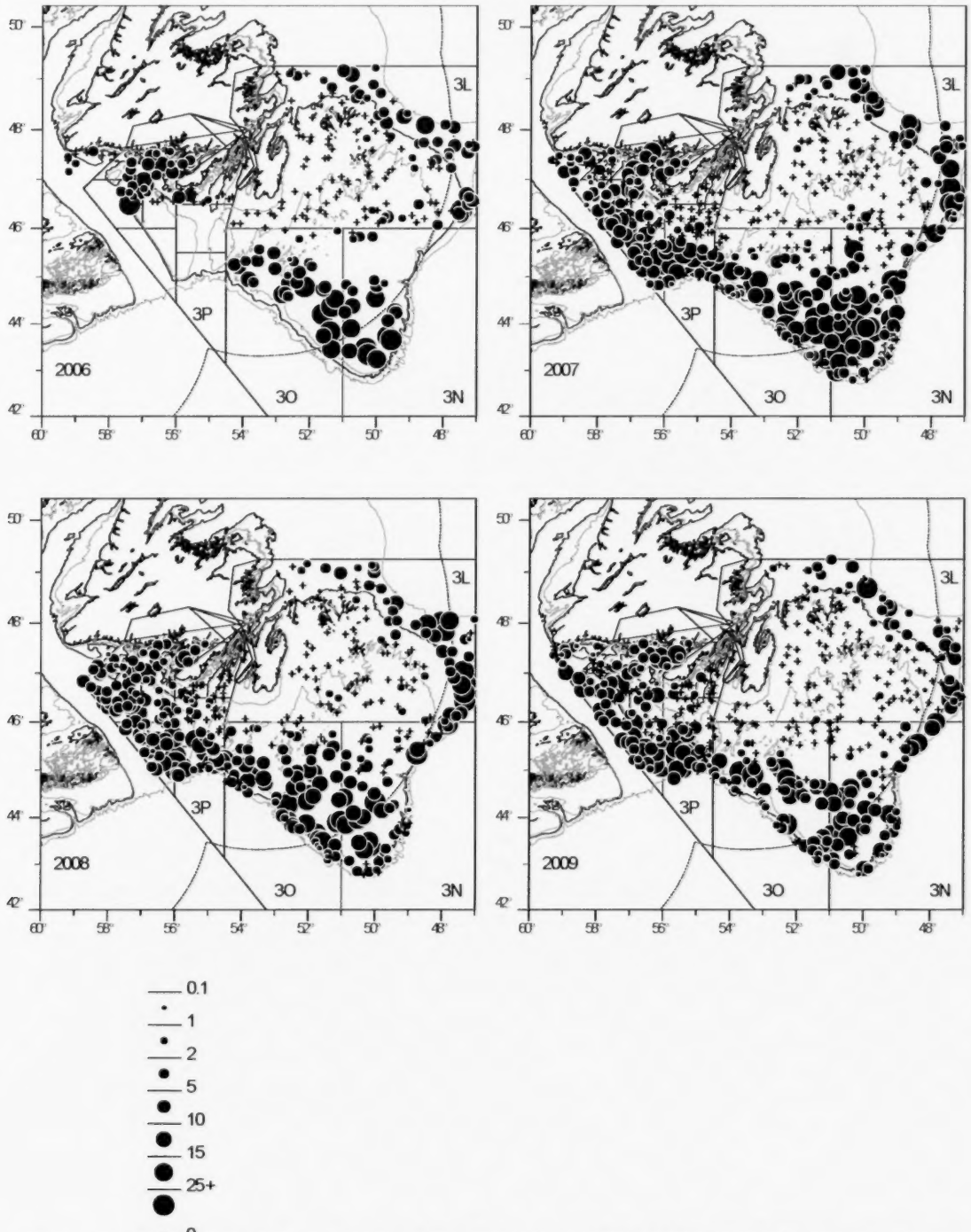

Figure 10d. Distribution of Thorny Skate on the Grand Banks (NAFO Div. 3LNOPs), based on Canadian spring surveys in 2006 (Upper Left), 2007 (Upper Right), 2008 (Lower Left), and 2009 (Lower Right). Note that Subdiv. 3Ps was not surveyed in 2006; nor was the deeper portion (>103 m) of Div. 3NO sampled in that year, due to mechanical difficulties on Canadian research vessels.

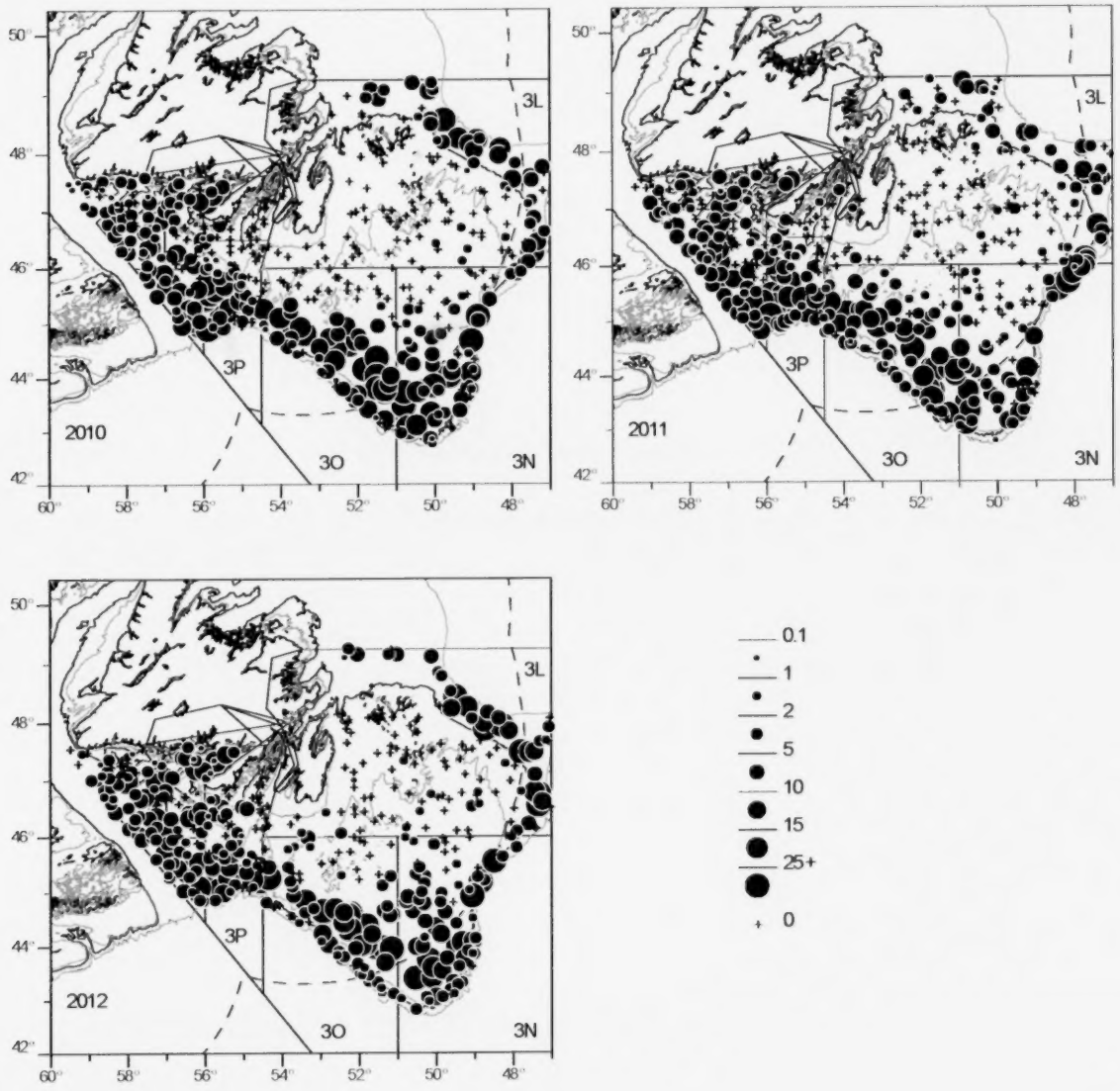

Figure 10e. Distribution of Thorny Skate on the Grand Banks (NAFO Div. 3LNOPs), based on Canadian spring surveys in 2010 (Upper Left), 2011 (Upper Right), and 2012 (Lower Left).

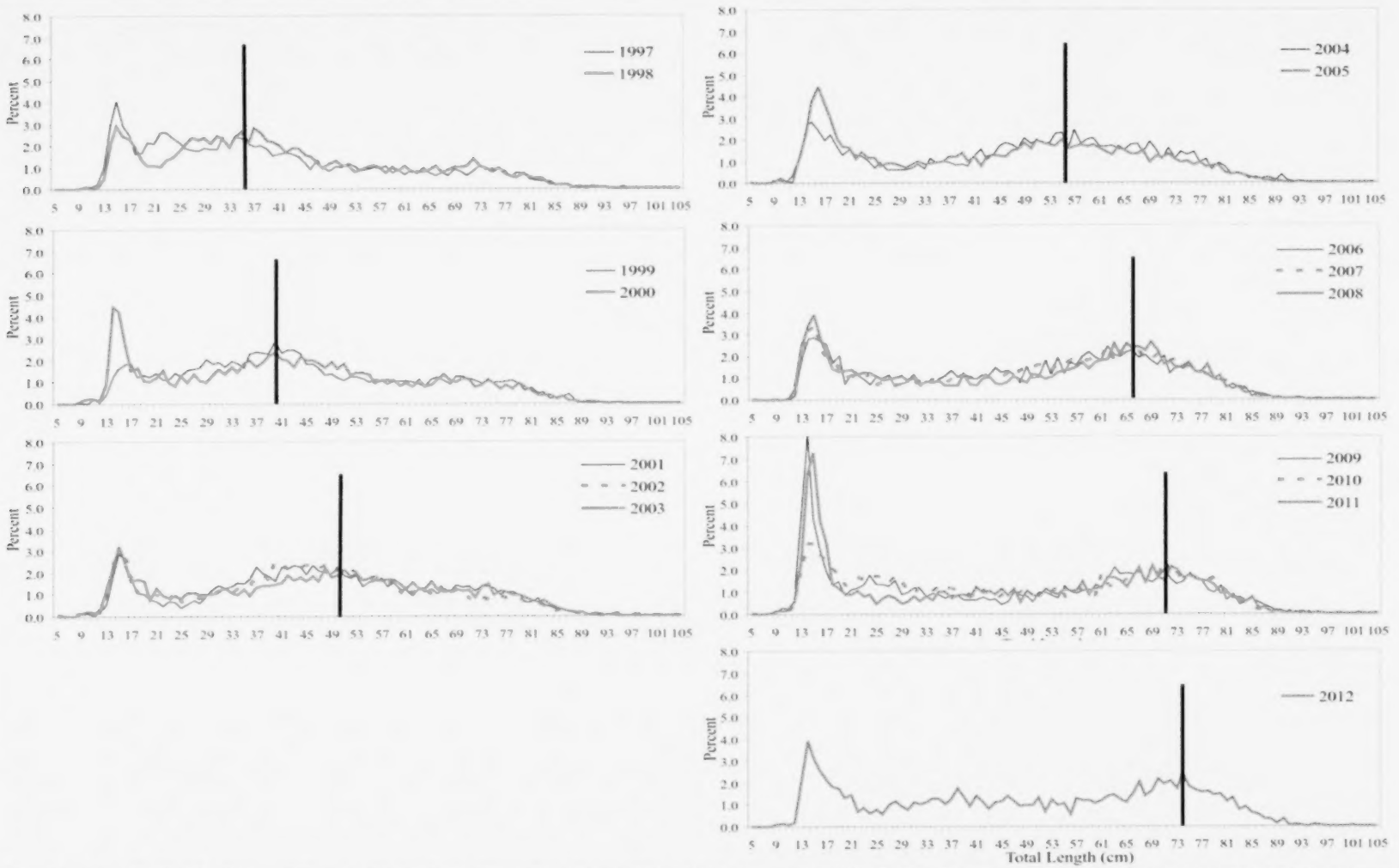

Fig. 11. Length distributions of Thorny Skate from Canadian Campelen spring surveys in NAFO Div. 3LNO and Subdiv. 3Ps, 1997-2011. Vertical bars represent dominant modes of immature skates (excluding YOY): 35 cm in 1998 (Top Panel); 40 cm in 1999-2000; 46 cm in 2002; 55 cm in 2004-2005; 66 cm in 2007, 69 cm in 2008, 71 cm in 2009-2010 (Bottom Panel), 72 cm in 2011, and 74 cm in 2012.

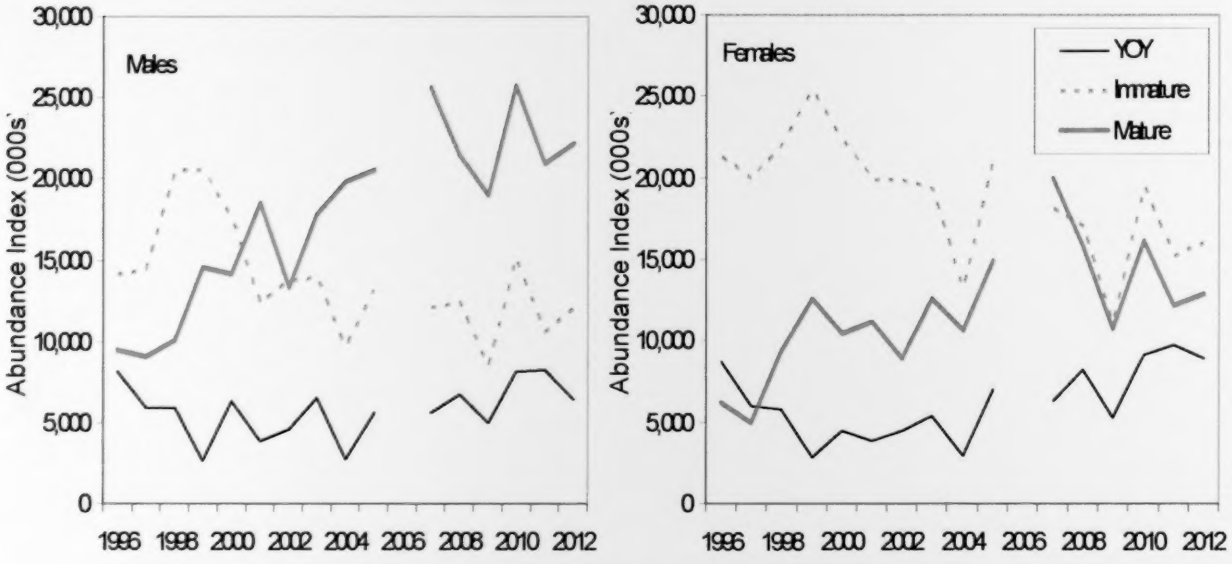

Fig. 12. Estimated abundances of male and female Thorny Skates by life stage in NAFO Div. 3LNOPs from Canadian Campelen spring surveys, 1996-2012. Note that Subdiv. 3Ps was not surveyed in 2006; nor was the deeper portion (>103 m) of Div. 3NO in that year, due to mechanical difficulties on Canadian research vessels.

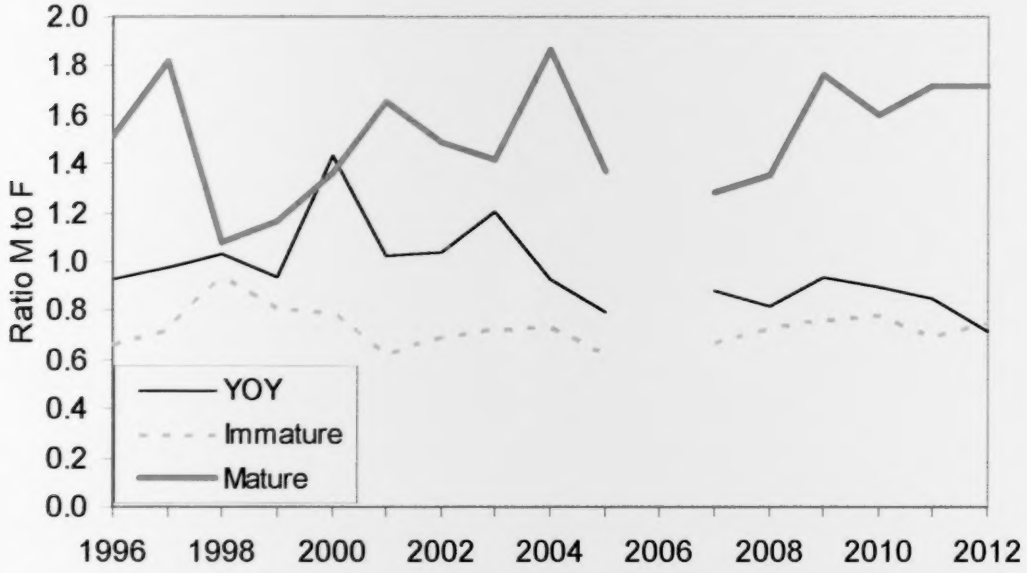

Figure 13. Ratio of staged male versus female Thorny Skates in NAFO Div. 3LNO and Subdiv. 3Ps from Canadian Campelen spring surveys, 1996-2012. Note that Subdiv. 3Ps was not surveyed in 2006; nor was the deeper portion (>103 m) of Div. 3NO in that year, due to mechanical difficulties on Canadian research vessels.

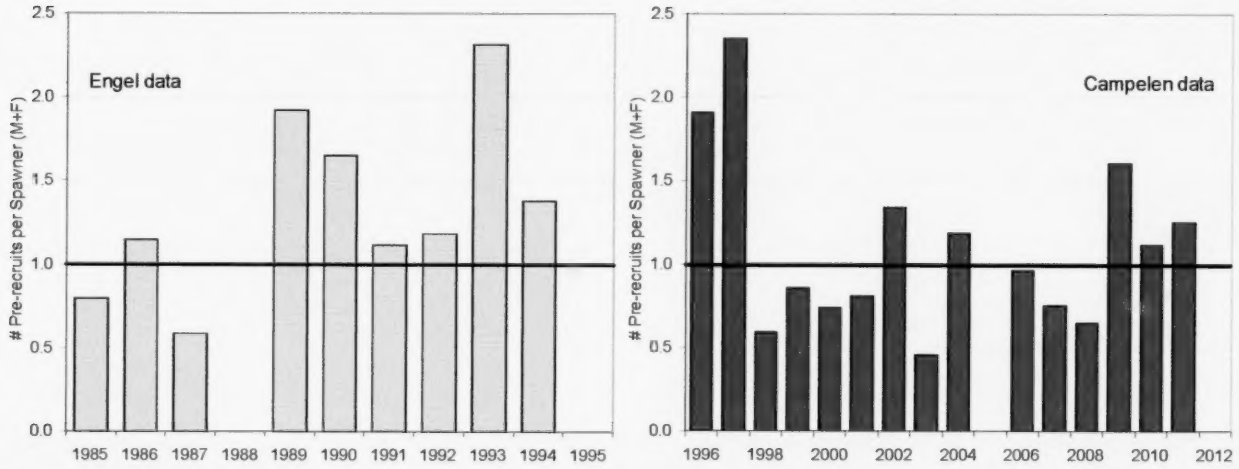

Figure 14. Pre-recruits per spawner expressed as number of male and female recruits (in year [y] produced per adult female in year [y-1]) from Canadian Campelen spring surveys in NAFO Div. 3LNO and Subdiv. 3Ps, 1985-95 (Engel; left panel) and 1996-2011 (Campelen; right panel). Note that Subdiv. 3Ps was not surveyed in 2006, and one-year-old skates in 2006 were caught only from the shallow (<104 m) portion of Div. 3NO due to incomplete survey coverage for that year. Both panels are not comparable due to different gear types.

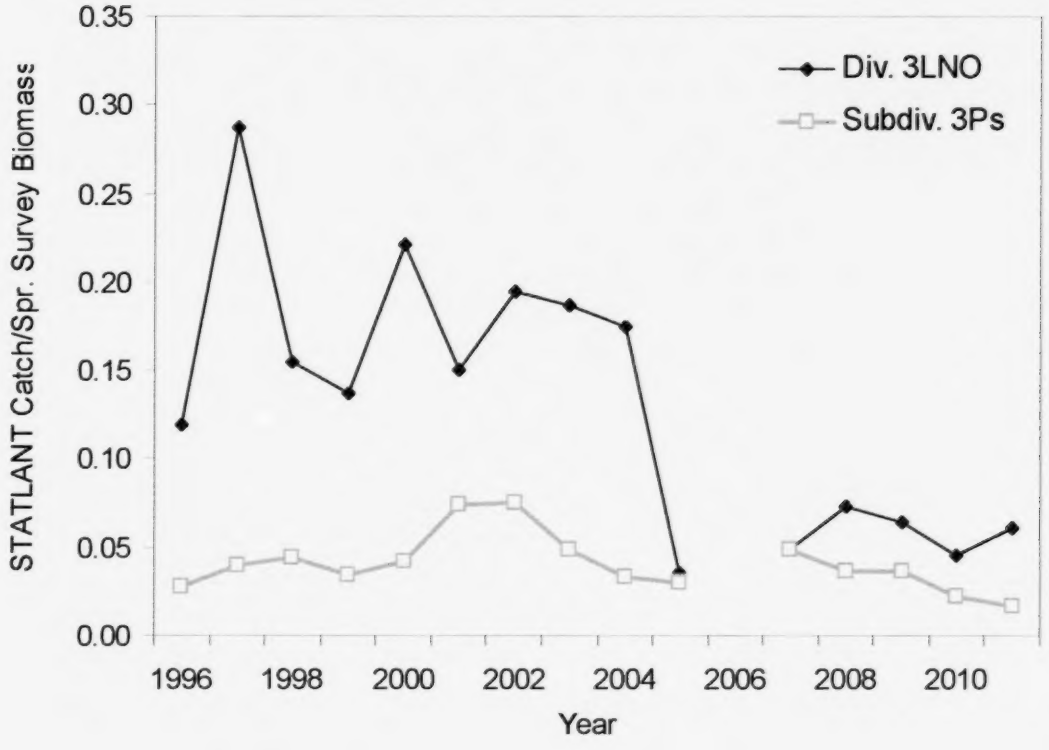

Figure 15. Fishing Mortality Index (catch/spring survey biomass) for Div. 3LNO and Subdiv. 3Ps, 1996-2011. Commercial catch estimates are NAFO STATLANT-21A data; biomass indices are from Canadian spring research surveys. Note that Subdiv. 3Ps was not surveyed in 2006; nor was the deeper portion (>103 m) of Div. 3NO in that year, due to mechanical difficulties on Canadian research vessels